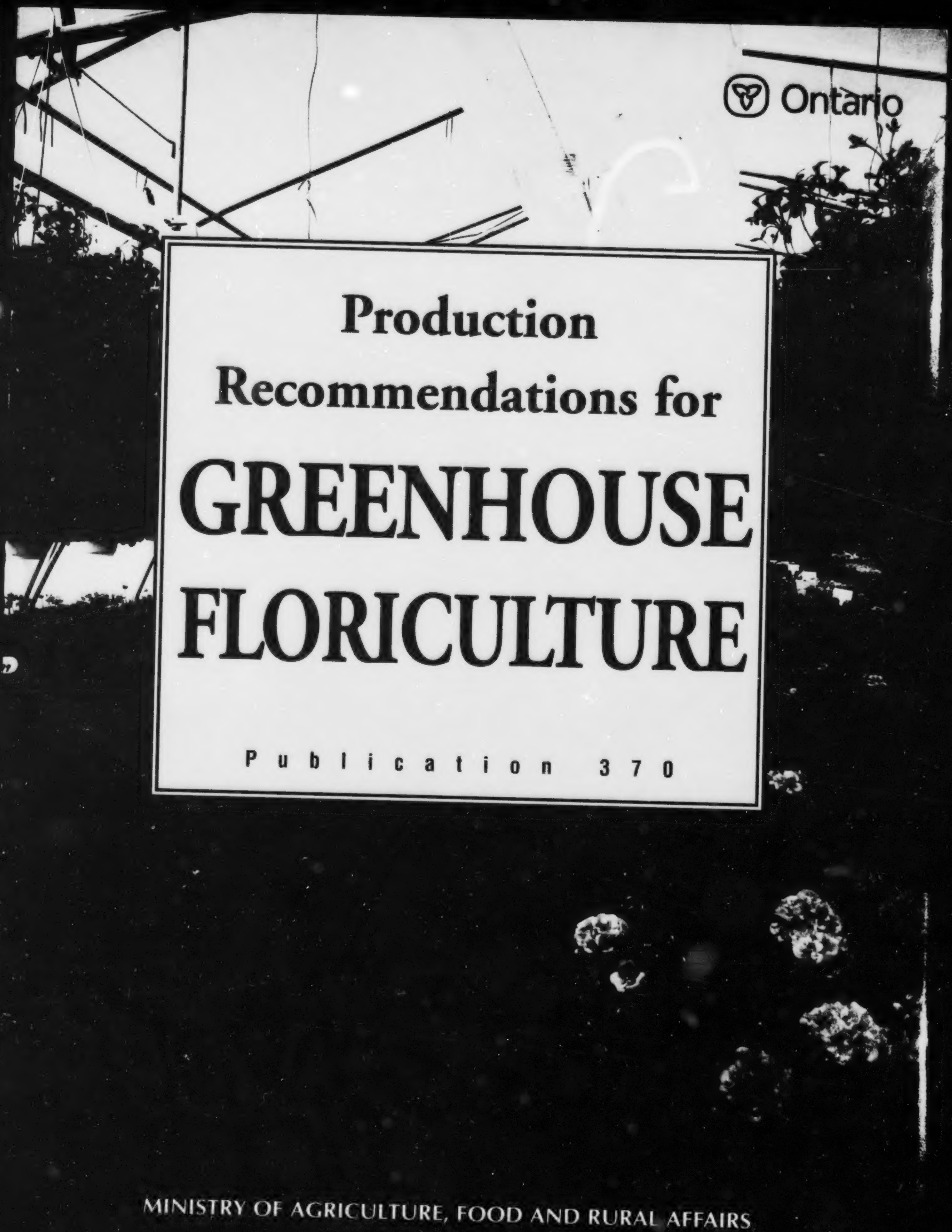


Ontario

Production Recommendations for
GREENHOUSE FLORICULTURE

Publication 370

MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

Each year the appropriate sub-committee of the Ontario Pest Management Research and Services Committee reviews the pesticides listed in this publication. To the best knowledge of the sub-committee, all of these pesticides were:

- federally registered
- reviewed by the Ontario Pesticides Advisory Committee and
- classified by the Ministry of the Environment as of November, 1999.

Discard old editions of this publication.

The information in this publication is general information only. All pesticides must be used in accordance with the product label and *Regulation 914* of the Ontario *Pesticides Act.*

Pay close attention to all instructions and warnings on the pesticide label.

By printing this publication, the Ministry of Agriculture, Food and Rural Affairs does not offer any warranty or guarantee, nor does it assume any liability for any crop loss, animal loss, health, safety or environmental hazard caused by the use of a pesticide mentioned in this publication.

Policy Statement

In this publication, most recommendations list several pesticides that can be used for each pest discussed. In general:

- the least hazardous materials and those that growers have used satisfactorily for years are listed first;
- the more toxic pesticides and/or newer ones with less practical, grower experience follow.

In some cases, the most effective pesticides are highly toxic.

This publication lists a number of brand names of pesticides. This is for the grower's convenience only. It is neither an endorsement of the product nor a suggestion that similar products are ineffective.

Weather and other factors influence the effectiveness of pesticides and the likelihood of plant injury by control chemicals. Consult the package label and other information regarding compatibility with other materials, the effect of high or low temperatures, poor drying conditions, and so on. Wettable or soluble powders (WP, SP,WDG or DG) are less likely to cause plant injury than liquid concentrates (EC, SC, and F).

Health Canada has established maximum residue limits (MRLs) for pesticides. However, growers should be aware that processors or retailers may demand more restrictive limits. Growers should seek advice of their intended market as to which restrictions or limitations apply.

Federal Registration and Provincial Classification

The Ministry of the Environment administers Ontario's *Pesticides Act* and *Regulation 914.*

All pesticides sold and used in Ontario must be:

- registered under the federal *Pest Control Products Act*, and
- classified under the provincial *Pesticides Act* by being placed in one of six schedules of the Ontario regulation.

Federal Registration

There are three federal registration categories.

1. **Full Registration**
   The federal government agrees the data package was acceptable at the time of registration.
2. **Temporary Registration**
   Additional scientific or technical information is required to obtain full registration. Temporary registrations expire after a specified time (one or two years).
3. **Temporary Registration (Restricted Class)**
   While the pesticide is urgently needed, studies on the safety of the product are incomplete. Such registrations expire on the 31st of December each year and the products must be re-registered yearly.

Provincial Classification

There are six classification schedules in *Regulation 914.* Pesticide products are classified on the basis of their toxicity, environmental or health hazard, persistence of the active ingredient or its metabolites, concentration, and usage. This system is needed to regulate the distribution, availability and use of pesticide products in Ontario.

For up-to-date information on the regulatory status of these or other pesticides contact the:

Pesticides Section,
Standards Development Branch,
Ministry of the Environment, Toronto.
Telephone (416) 327-5519

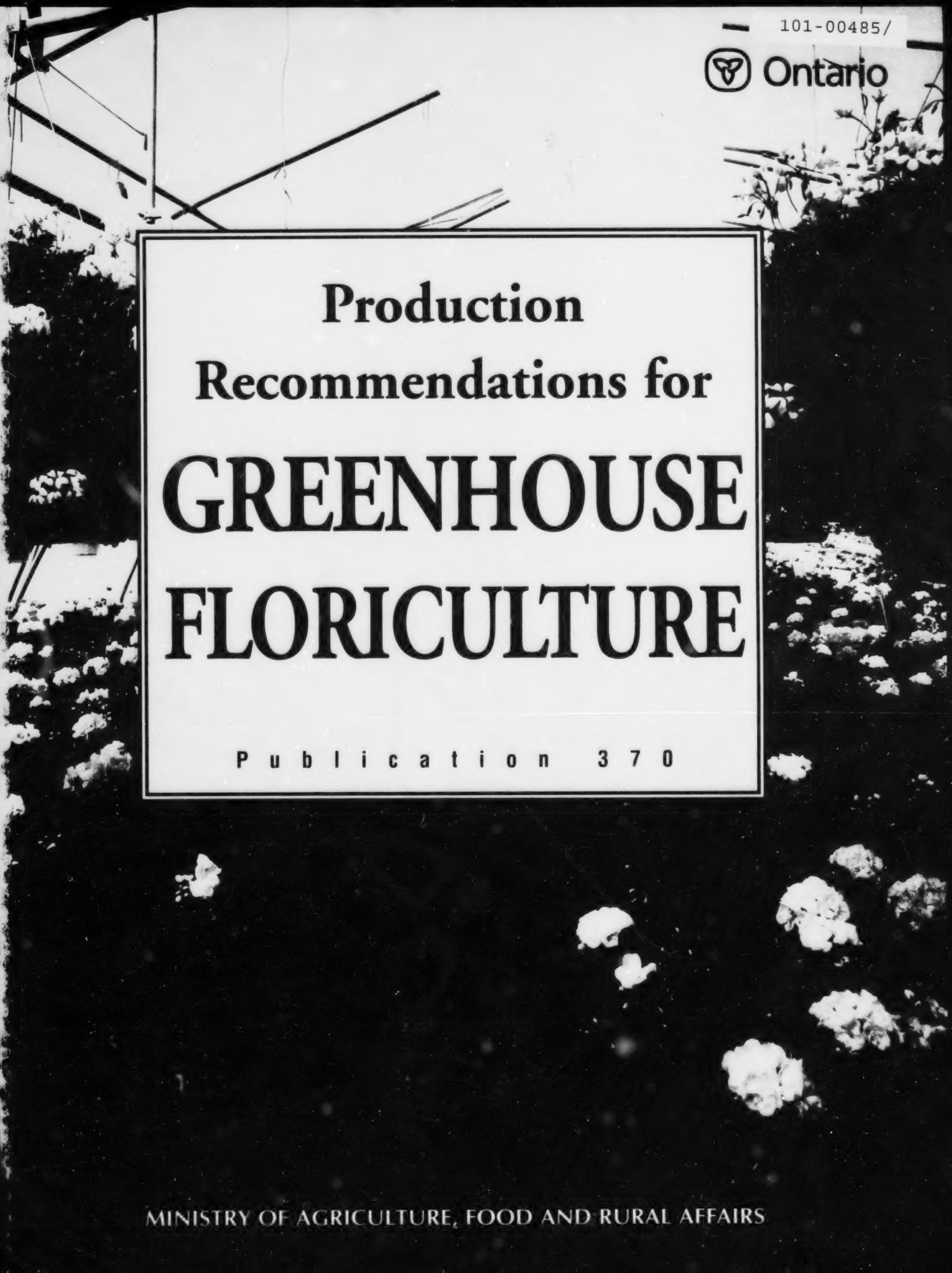
Farmer Certification

Agriculturists must be certified through the Grower Pesticide Safety Course to purchase and use Schedule 1, 2 or 5 pesticides. Effective January 1, 2000 agricultural assistants must complete Ministry of the Environment-approved training before they can handle Schedule 2 or 5 products under the supervision of a Certified Grower. Trained Assistants also have some restrictions of duties. For more information please call the Ontario Pesticide Education Program at 1-800-652-8573.

Cette publication est aussi disponible en français.

101-00485/

Ontario



Production Recommendations for

GREENHOUSE FLORICULTURE

Publication 370

MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

Looking for greenhouse production information on the Internet?

www.gov.on.ca/OMAFRA/english/crops/hort/greenhouse.html

It's one-stop shopping for information regarding the production and maintenance of greenhouse crops.

Acknowledgements

The recommendations contained in this publication have been prepared in consultation with:

- Ontario Pest Management Research & Services Committee
- Ontario Hort Crops Soil Management Research and Services Committee
- Ontario Horticultural Crops Research & Services Committee

And personnel of:

- Crop Technology, OMAFRA
- University of Guelph
- Plant Products Co. Ltd.

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1. Precautions with All Pesticides

General Precautions

- Before opening pesticide containers, always read the label and follow all precautions and directions.
- Keep a record of the common names of all the pesticides you handle, especially those listed as hazardous in this publication. *Other members of your family need to know about this list in case there is an accident.*
- Never smoke, chew tobacco, or eat while handling or applying pesticides. Do not carry tobacco or food in clothes worn while spraying.
- Change your clothes and wash before eating.
- When handling and mixing pesticide concentrates, rinsing empty containers, tending to stoppages, or repairing leaks, wear a full set of protective clothing. This includes a waterproof cap, coveralls, impervious gloves, boots, and safety goggles.
- If you are using highly or extremely toxic pesticides or very dusty formulations, wear a respirator. If you are handling dusty formulations, wear a dust mask. If you are handling volatile compounds or gases, you must wear a respirator. If these gases are highly dangerous or you are handling them in an enclosed space, you may need a self-contained breathing apparatus. Make sure you follow the specific instructions on the pesticide label.
- When you draw water from wells, ponds, streams, or other sources, use an anti-backflow device to prevent back-siphoning.
- Mix pesticide at least 50 m from wells, ponds, or streams. Triple or pressure rinse the empty container and add the rinse water to the tank. Mix only enough solution to do the spray job.
- When you have finished loading and mixing, wash your gloves and boots with clean water before removing them.

  Always read the label and follow the instructions on it.
- During application, a tractor cab with charcoal filter gives adequate protection against exposure.
- When using air-blast and mist blowers or when in tractors without cabs, wear waterproof suits and caps and impervious gloves and boots. When applying fumigants in the field, have a respirator on hand in case you need to deal with equipment problems or in case inadequate sealing in the soil allows the fumigant to escape.
- When the spray operation is done, bathe or shower to remove pesticide deposits on your skin. Do not handle anyone or anything in your home before you bathe.

Preventing Farm Water Supply Contamination

It is an offence to contaminate wells, ponds, streams, and surface waters with pesticides. Taking the following steps will help prevent contamination:

- Keep pesticide concentrates above the flood plain in locked storage.
- After emptying, triple or pressure rinse, crush, and dispose of containers.
- Return empty plastic or metal containers to a dealer who participates in the container-recycling program.
- Empty bags may be burned or disposed of at a landfill site.
- Mix concentrates and water at least 50 m away from any water supply.
- Use buffer zones and berms to avoid contaminating surface water, wells, ponds, and streams.
- Do not use drinking water sources to fill spray equipment. If you fill your tank from a well, lake, river, or other surface water source, you must use an anti-backflow device.
- Do not spray within 10 m of shallow wells or 5–10 m of other water supplies in ideal weather and farther away if there is any air movement.
- Stop spraying when wind velocity reaches 10 km/hr.

If an Accident Occurs

- Wash your gloves, boots, and respirator before removing them.

- Take off your clothing, including underclothes, immediately and wash contaminated skin thoroughly with soap and water.
- Soak clothes immediately and *double* launder them as soon as possible.
- If the spill was serious, place the clothes in a plastic bag and dispose of them in a safe manner.
- Wash your gloves, boots, and respirator again.
- If clothing becomes wet with a pesticide, remove clothing immediately, wash, and put on fresh clothes.

  If a pesticide gets on your clothes, always remove these clothes immediately!
- If symptoms of illness occur during or shortly after handling a pesticide, go to a hospital. Take your list of common-name chemicals with you. ***(See Emergency and First Aid Procedures for Pesticide Poisoning on the inside back cover.)***
- Clean up any pesticide spills immediately.
- In the case of minor spills, use dry soil or other absorbent material such as kitty litter to remove excess liquid. Sweep up powders and granulars.
- Contaminated soil and sweepings should be spread over a large area of bare soil to facilitate rapid degradation.
- Make sure you are adequately protected when cleaning up the spill.

For information on preventing spills, see the OMAFRA factsheet, *Ways to Avoid Pesticide Spills,* Order No. 96-025.

In the case of a major pesticide spill, you must notify the Ministry of the Environment, Spills Action Centre, 5775 Yonge St., Suite 1005, Toronto, Ontario, M2M 4J1, 416-325-3000 or 1-800-268-6060.

Emergency procedures for pesticide poisoning and important first-aid information appear on the inside back cover of this book.

Relative Toxicity To Applicator

Toxicity Definitions

Lethal Dose 50% (LD$_{50}$)

The dose that, when administered, will kill 50% of the test animals within a stated period.

Acute Toxicity

Immediate adverse effects from a single or short period of exposure to a substance by the oral, dermal, or inhalation route.

Chronic Toxicity

Adverse effects resulting from repeated exposure to a substance over an extended period.

High Acute Toxicity

These pesticides are extremely dangerous if handled carelessly. The acute oral LD$_{50}$ is less than 50 mg/kg of body weight, and the acute dermal LD$_{50}$ is less than 200 mg/kg body weight.

- These pesticides can be fatal if you ingest or absorb less than 0.1 to 3.0 mL (1 drop to half a teaspoon).
- These pesticides are labelled with the skull and crossbones in a stop sign.
- You must use a respirator and eye protection along with all other protective clothing when using these products.

Moderate Acute Toxicity

These pesticides are dangerous if handled carelessly. The acute oral LD$_{50}$ is 50–500 mg/kg of body weight, and the acute dermal LD$_{50}$ is 200–2,000 mg/kg body weight.

- These pesticides can be fatal if you take 3–30 mL (half a teaspoon to 2 tablespoons).
- These pesticides are labelled with the skull and crossbones on a stop sign.
- You should wear a respirator when handling these concentrates.

Bendiocarb	(Trumpet)
Deltamethrin	(Decis)
Diazinon	(DZN 600EW)
Endosulfan	(Thiodan)

Low Acute Toxicity

These pesticides are not fatal unless ingested in amounts of over 30 mL (1 oz). The acute oral LD$_{50}$ is greater than 500 mg/kg body weight, and the acute dermal LD$_{50}$ is greater than 2,000 mg/kg body weight.

- Pesticides that are mentioned in this publication, but are not in the lists in this section, have low acute toxicities.
- You should handle these pesticides with caution.
- You must wear protective clothing.
- You should wear safety goggles, and, if using these products in a confined space, use a respirator.

Chronic Toxicity

It is not possible to assess chronic toxicity of a pesticide in the same way an LD_{50} is used to determine acute toxicity. Instead, a number of tests performed on animals help predict whether a pesticide may cause long-term effects.

- Animals are examined for many toxic effects such as the production of tumours or abnormalities.
- Using protective clothing and equipment will help reduce exposure and the risk of chronic effects.

Entering Treated Areas

Workers may be poisoned if they enter greenhouses without protective clothing and equipment too soon after pesticides have been applied. Such poisoning can result from handling treated plants or from inhaling pesticide vapours. The list below shows a specific minimum interval that you must observe between applying a pesticide and working in the crop without protective equipment. If no re-entry period is given on the label, do not enter until the crop is dry, or in the case of smokes, the greenhouse has been properly ventilated.

12 Hours	Dyno-Mite, Decis
24 Hours	Trumpet

Blood Tests for People Applying Pesticides

Organophosphorus and carbamate pesticides can inactivate serum and red blood cholinesterase levels. If cholinesterase activity falls below a critical level, poisoning can result. Symptoms include fatigue, dizziness, nausea, trembling, blurred vision, and difficulty breathing.

If you use the pesticide groups listed below, have your family doctor check your cholinesterase levels. The tests should be started before you use these pesticides-normal levels of cholinesterase can vary considerably, making it difficult to assess the degree of suppression. In this publication, the pesticides of primary concern are:

Bendiocarb	(Trumpet)
Pirimicarb	(Pirliss)
Acephate	(Orthene)
Sulfotep	(PlantFume 103)
Diazinon	(DZN 600EW)
Dichlorvos	(DDVP)
Malathion	(MALATHION 50%EC)

Protective Outdoor Clothing and Equipment

Why Use Personal Protection?

Pesticide formulations vary in toxicity from slightly poisonous to extremely poisonous. Exposure occurs once the pesticide is removed from the container. The toxicity of the pesticide and exposure to the user create a hazard. Both can be reduced—toxicity by dilution and exposure by protective clothing.

You can reduce the hazards of spraying and thus the risk of poisoning. Wearing protective clothing and equipment reduces the risk.

Reducing Exposure

Exposure can be through skin, eyes, mouth, or nose. About 80%–85% of the exposure in most spray operations is during mixing and loading concentrate. Field application usually accounts for 15%–20% of the exposure. Skin exposure is usually 90%–100% of the total exposure. About 70% of this is by way of the hands and forearms, and 30% involves the rest of the body. Inhalation (nose and mouth) exposure is normally 0.1% but rises to 5%–10% with mist blowers and air-blast sprayers.

Stage	Risk
Handling and mixing concentrate	very high
Rinsing empty containers	high
Applying outdoors	low–high
Applying indoors	medium–very high
Cleaning up, rinsing equipment	medium–high
Entering treated area within 48 hours	low–very high

Protective Clothing

- To reduce skin (dermal) exposure, wear impervious gloves. Always refer to the product label, and unless the label says otherwise, use neoprene or nitrile gloves. Always wear waterproof boots, along with coveralls, apron, or spray suits, and a waterproof cap.
- Coveralls can be reusable or disposable. Reusable coveralls are normally cotton or polyester and should be tightly woven. It's easier for pesticides to penetrate polyester than cotton. Disposable coveralls are polyethylene and may be laundered several times. Spray suits should be used in highly hazardous conditions, such as with mist blowers and air blast machines.
- Protect your eyes with safety goggles when working with any pesticide concentrate.

Respirators

- Use respirators when handling pesticides with labels that call for respiratory protection (they carry the warning stop sign with skull and crossbones).
- Use respirators when spraying any pesticide rated as high toxicity or when applying any liquefied gas.
- Respirators are available as air purifiers or self-contained units and come in a wide range of shapes and sizes. Consult the label and your nearest safety supply company for advice.
- Make sure the cartridge or canister you use has a safety-approved sticker with the letters NIOSH (National Institute for Occupational Safety and Health) on it.

Washing Protective Clothing

- To keep your protective clothing and equipment functional, clean it thoroughly.
- Never let children or pets be exposed to contaminated clothing or equipment.
- Launder clothing promptly, wash and store other personal protection items, and rinse spray equipment before storing it to prevent children from playing with it.

Fabric Clothing

- If fabric is saturated with the concentrate of a highly toxic pesticide, throw it out.
- Wear nitrile or neoprene gloves when handling severely contaminated clothing.
- Remove the clothing carefully, immediately put it in a plastic bag, and dispose of it in a safe manner. ***For a normal spray operation, follow these guidelines, preferably twice a day, but at least at the end of the work day:***
- Rinse clothing outdoors.
- Soak and wash clothing separately.
- Soak clothes, with detergent, in a container such as a large bucket or tub; or use the pre-wash cycle of an automatic washer along with detergent. Prewash solvent-based products work on EC formulations.
- Wash only a few garments at a time.
- Use heavy-duty liquid detergents.
- Use hot water, the highest water level, and a hot super-wash cycle.
- Do two complete wash cycles, each with a double rinse.
- After washing, run the empty washer through another wash cycle with detergent to decontaminate the washing machine.
- Hang the clothes to dry, outside if possible, to avoid a potential buildup of pesticide residue in the dryer.

Rubber, Vinyl, or Plastic Boots and Gloves

- To avoid getting pesticide on your hands, wash the outside of your boots and gloves with detergent and water before taking them off.
- After removing boots and gloves, wash them inside and out with detergent and water, rinse them thoroughly, and dry them in a well-ventilated area.

Chemical-Resistant Clothing, Goggles, and Face Mask

- Wash plastic or rubber clothing and equipment with detergent and water and rinse thoroughly.
- Dry in a well-ventilated area.

Respirators

- Make a note of the date the cartridge is first used.
- Discard cartridges, canisters, and filter pads when breathing becomes difficult, when you notice a pesticide odour, or at the interval set by the manufacturer.
- Remove cartridges and filter pads from the face piece and store them in clean, sealed plastic bags.
- Wash the face piece in detergent and water, rinse it thoroughly, and dry it in a well-ventilated area.
- Never use alcohol or other solvents for cleaning respirators, as the rubber and plastic will be damaged.

Safety Supply Houses

Consult a safety supply house for help in selecting your protective clothing.

TABLE 1–1. Safety Supply Companies in Ontario Providing Protective Clothing or Respiratory Devices

Optical	Aearo Canada Ltd. 7115 Tomken Road, Mississauga, Ontario L5S 1X7	(905) 795-0700 888-387-9681	*Branches:* Mississauga, Gravenhurst
H.S. Cover Survivair	Levitt-Safety Ltd., 2872 Bristol Circle Oakville, Ontario L6H 5T5	905-829-3299 888-453-8488	*Branches:* Kitchener, London, Oakville, Ottawa, Sarnia, Stoney Creek, Sudbury, Thundor Bay
Kasco Helmets	The St. George Co., P.O. Box 430, 20 Consolidated Drive Paris, Ontario N3L 3T5	519-442-2046 800-461-4299	www.thestgeorgeco.com
Mine Safety Appliances	MSA Canada Inc., 148 Norfinch Drive, North York, Ontario M3N 1X8	416-667-9400 800-267-0672	
3M Canada Inc. Occupational and Environmental Safety Division	A wide range of distributors; contact P.O. Box 5757, London, Ontario N6A 4T1	519-451-2500	
North Safety Products Ltd.	26 Dansk Court, Toronto, Ontario M9W 5V8	416-675-2810 800-268-6925	
Racal Airstream, Scott, Willson	Acklands-Grainger Inc. 90 West Beaver Creek Road, Richmond Hill, Ontario L4B 1E7	800-387-5744	*Branches:* Hamilton, Kingston, Kitchener, London, St. Catharines, Sarnia, South Porcupine, Thunder Bay, Windsor
Medical Safety First Aid	Kit Care Corp., 91 Kelfield St., Unit 6, Rexdale, Ontario M9W 5A4	416-243-3030	*Branches:* Kitchener, London, Orillia, Ottawa, St. Catharines, Stoney Creek

Many of these companies also have dealer outlets. For details contact the supply company

Protective Devices for Use in Enclosed Areas

Canister Gas Masks

- Canister gas masks are effective for protection against certain harmful gases, vapours, and particulate matter.
- They are generally suitable for ventilated areas not subject to rapid change but should never be used in confined spaces where oxygen deficiency and high gas concentrations may occur.

Self-Contained Breathing Apparatus

- Air-purifying devices do not work in confined spaces where gas concentrations are unusually high. The lack of oxygen can prove fatal. Under these conditions, you need an air supply provided by a self-contained breathing apparatus (e.g., a *Scott Air Pack*).
- Substances that produce hydrogen cyanide, methyl bromide, chloropicrin, or phosphine can cause high gas concentrations and oxygen deficiency, as can smoke generators, foggers using highly toxic pesticides, and some volatile sprays.

Other Protective Clothing

- Wear other protective clothing in keeping with requirements listed on the pesticide label.

Working Conditions

- Use canister gas masks when the surrounding air contains low concentrations of toxic gases, vapours, or particulate matter derived from soil-drench, granular, dust, or foliar-spray applications.

Pesticides applied in this manner usually have moderate to low toxicity.

- You must use a self-contained breathing apparatus (e.g. a *Scott Air Pack*) when applying highly toxic pesticides. These can produce high concentrations of toxic gases, vapours, or particulate matter, and a lack of oxygen, especially in an enclosed space (e.g., when fumigating grain).
- Contact your safety supply company for their recommendation.

Space Fumigants and Insecticide Smokes

- Learn about the health hazards and toxic properties of the pesticide you are using.
- When using fumigants or insecticide smoke generators, wear protective clothing to prevent skin and inhalation exposure. During and after treatment, lock the building and post warning signs.
- Follow instructions on the product label regarding aeration of treated buildings, warehouses, grain storage bins, or other enclosed areas before letting anyone enter.

Fumigants

- Always consult the product label.
- An agriculturalist using methyl bromide plus chloropicrin or aluminum phosphide to fumigate greenhouses, vaults, warehouses, and grain storage must obtain a permit issued under the *Pesticides Act.*
- To apply for a permit, contact the local pesticides officer at the *Ministry of the Environment.*
- Remove livestock and poultry that are in the building to be fumigated, especially if they are under the grain bin.
- As a safety precaution, have someone else who is wearing personal protective equipment help with the fumigation.
- When handling methyl bromide, do not wear gloves because these will trap gas next to the skin. You must wear a full-face respirator with organic vapour canister or positive-pressure breathing apparatus.
- When handling aluminum phosphide, use cotton gloves and wear a full-face mask respirator with an acid gas canister.
- For more information, obtain *Methyl Bromide Structure Fumigation Procedures and Aluminum Phosphide Structure Fumigation Procedures* from the Ministry of the Environment.

Storing Pesticides

- The Ontario *Pesticides Act and Regulation 914* require that all pesticides be kept out of the reach of children, irresponsible persons, pets, and livestock. They should be stored in a locked facility away from food and feed.
- Herbicides should be stored separately from other pesticides to avoid contamination.
- Always store pesticides in their original containers and keep them tightly closed.
- Never put pesticides in unmarked containers.
- In areas where flooding has been frequent, you must store fertilizers and pesticides above the known high-water mark.
- Contamination of water by these chemicals has led to serious health problems for humans and domestic animals as well as fish and wildlife.
- See also the OMAFRA factsheet, *Pesticide Handling Facilities*, Order No. 94-037.

Schedule 1, 2, and 5 Pesticides

- Schedule 1, 2, and 5 pesticides must be stored in a locked facility that is ventilated to the outside.
- A sign that says **CHEMICAL STORAGE WARNING—AUTHORIZED PERSONNEL ONLY** in block capitals must be fixed to the outside of each entrance.
- Only a certified agriculturalist or someone under that person's supervision can enter the storage facility.

Disposal of Pesticide Containers or Contaminated Material

- All paper or cardboard pesticide containers, paper packaging material, or other paper material used to clean up spills should be burned or disposed of at a landfill site.
- Make sure that people and animals are kept away from the smoke and that the smoke is not directed toward buildings, highways, roads, or outdoor public areas.
- Plastic material must not be burned.
- Unrinsed containers can contain as much as 3% of the original formulation. If this amount of toxic pesticide is discarded with the container, it could be dangerous to other people handling it or to the environment (e.g., your water supply). Failure to rinse is also wasteful; use that 3% to control the pest.
- Rinse all metal, plastic, or glass containers *three times* with water and add the washings to the spray tank. Alternatively, use a rinsing device. Rinsers

can be used to puncture the bottom of a metal or plastic container and rinse the residue directly into the spray tank. This procedure takes less than a minute.
- Return the rinsed containers for recycling to any dealer cooperating in the pesticide container collection and recycling program.
- Dispose of unwanted or contaminated pesticide through *Laidlaw Environmental Management* (519-451-6630) or contact the appropriate registrant to develop an alternative method acceptable to the Director under the *Pesticides Act* (416-327-5519).

Types of Application Equipment

Spraying

- Spraying is one of the most widely used and effective methods of applying pesticides.
- The nozzles should be clean and pressure maintained to achieve a fine spray that will result in uniform coverage when the mixture is applied up to the point of runoff.
- Complete coverage is the objective; be sure to spray both the lower and upper leaf surfaces thoroughly.

Fogs

- Fogs are produced by several kinds of machines.
- These machines all use heat from different sources to vapourize the pesticide.
- Fogging can be a very efficient method of pesticide application provided the operator follows the basic instructions.

Granular Application

- Several types of applicators are available for applying granular pesticides.
- Be sure the applicator does not grind or fracture the granules.

Smokes

- Smokes are a very simple but effective means of pesticide application.
- There is no equipment involved; containers are simply placed on the path and lit.
- Do not use smokes in very old, loose greenhouses or during high winds.

Ultra-Low Volume

- There are several types of ultra-low volume (U.L.V.) applicators available.
- They atomize the pesticide solution into an extremely small particle size (7–20 microns).
- Distribution through the greenhouse is by a forced-air fan system.

Electro-Static Sprayers

- Electro-static sprayers (E.S.S.) add an electrical charge to the fine spray particles.
- This enhances plant coverage by the pesticide and reduces drift.

Wetting Agents

In the following discussion, the term "wetting agent" includes spreaders, stickers, and surfactants, although these terms do have slightly different technical meanings.

- Water will not always spread evenly over a surface. Its hydrophilic nature creates a high surface tension so that, when placed on a leaf (hydrophobic) surface, it forms large droplets that easily roll (with the pesticides) off the leaf and onto the ground.
- Reducing the water's surface tension by adding a wetting agent allows the water to make better contact with the leaves. Consequently, the pesticides spread more evenly over the leaf surface.
- Most pesticides are formulated with a wetting agent in them. However, in some cases (due to air or water temperature, water hardness, type of leaf surface, stage of plant growth, and/or the type of formulation), the amount may not be adequate. Consult the label for specific recommendations.
- A simple method of determining if the amount of wetting agent present is sufficient is to spray about 3 m of bed area. Examine both the upper and lower surfaces of leaves at different growth stages for evidence of uniform wetting.
- If wetting is not uniform, add 125 mL of spreader per 1000 L of spray. Spray another 3 m of the bed and re-examine. Continue until wetting is satisfactory.
- Wetting agents help the spray solution to wet powdery mildew mycelium, improving control. However, an excessive amount of wetting agent can cause plant damage, excessive foaming (which will cause pumping problems), or runoff (resulting in poor control).

Water for Irrigation and Pesticide Application

It is very important to neutralize alkaline water when using the water for irrigation and pesticide spray-tank mixtures.

Irrigation

- For crop irrigation, water should have a pH in the 6.0 range (acidic) in order to improve nutrient uptake. Many water sources in Ontario have a high pH (alkaline), which must be lowered.
- By testing the water, you can determine both the quantity and type of acid that must be added to achieve the desired pH level. Consult your Greenhouse Crop Advisor and see section on Crop Nutrition.

Pesticide Spray-Tank Mixtures

- Because many pesticides decompose in alkaline water, try to use pesticides diluted with alkaline water immediately.
- However, spraying immediately is not always possible. Note that any delay in applying spray mixtures will result in pesticide loss due to decomposition and, possibly, a corresponding decrease in control. To avoid this possibility, neutralize alkaline water before adding any pesticides. Dissolve ammonium dihydrogen phosphate at the rate of 50 g/100 L water first, then add pesticides.
- The rate of decomposition depends on the pesticide, the concentration of pesticide in the tank (dilution factor), and the temperature of the water.
- The phosphate is not always necessary, but this practice provides insurance against pesticide loss. Phosphate costs substantially less than pesticides, and the added phosphate will be available as a foliar nutrient.
- Water-soluble fertilizers are used occasionally with pesticides as a tank mixture. In this case, it is important to choose acidic fertilizers (which make the addition of ammonium dihydrogen phosphate unnecessary). Do not use alkaline fertilizers for this purpose; the amount of phosphate recommended above will not be sufficient to neutralize the water, and pesticide decomposition may increase.

Agribrom

- Agribrom is registered for use as a water treatment to control algae.
- To be effective, it must be constantly present in the irrigation water at a low level.
- If irrigation water is being recirculated, and Agribrom is added every time the water is reused, monitor chloride levels and suspend use if chloride levels are high.
- Treating reservoir water may also elevate chloride levels, so it is advisable to inject Agribrom just as the water is applied to the crop.
- Follow label directions carefully.

Wood Preservatives

- Wolmanized® lumber is safe for greenhouse use.
- Copper napthanate has caused some crop injury to poinsettia.
- Other wood preservatives should not be used. Check with your Greenhouse Crop Advisor.

New Pesticide Packaging Method

To simplify disposal of empty pesticide packages, the industry has re-introduced a soluble package that dissolves in the tank of the farm sprayer.

- Water-soluble packaging under the names such as *Clean Pak, Solupak,* and *Toss-N-Go* is used for dry flowable and wettable powder pesticide formulations.
- In most cases, the water-soluble packaging material is PVA (poly vinyl alcohol). This material dissolves completely when added to the water in the sprayer tank according to instructions.

Handling

- Do not allow water-soluble pouches to become wet prior to adding them to the sprayer tank.
- Do not handle the pouches with wet hands or wet gloves.
- Do not remove water-soluble pouches from the overwrap (outer package) except when adding them to the sprayer tank.
- Always reseal the outer package to protect the remaining pouches from moisture.

Mixing

- After spray tank is one-quarter full of water and the agitator is running, add the water-soluble pouches to the tank.
- Depending on the water temperature and the degree of agitation, these pouches dissolve completely within 5 minutes.
- As tank continues to fill, add any other compatible pesticides.

Compatibility

- Do not add a pesticide that is incompatible with the PVA packaging material. The PVA material is not soluble with summer-type oils (e.g., Superior Oil).
- Do not combine with the pouches any material containing boron (e.g., Solubor), chelated micronutrients, or water-soluble fertilizers. The combination is likely to cause a sticky, insoluble substance in the tank.
- After applying boron, chelated micronutrients, or water-soluble fertilizers, completely empty and rinse the spray tank before using any product packaged in PVA.
- Read all labels and instructions carefully. For more details, contact your farm chemical dealer.

Pesticide Concentration

- Brands of a pesticide from different companies often contain different concentrations of the same chemical.
- If you use a brand with a concentration different from that listed in this publication, you will need to adjust the rate of application to apply the same amount of actual chemical (active ingredient).

Seed Treatments

- Seed dressings or treatments are poisonous to people and livestock.
- Do not inhale the fumes or dust when treating or handling treated seed.
- Wear neoprene or nitrile gloves.
- Wash all residue of these chemicals from your skin after finishing the treatment. Chemically treated seed is poisonous.
- Never feed surplus seed to livestock. Destroy all the bags that have held treated seed as recommended in the Container Disposal section of this publication.

2. Crop Nutrition

Introduction

Living plants consist of water (≈90%), organic matter (4–10%), and minerals (15%). The organic matter is produced by photosynthesis in the green leaves, while water and minerals are generally taken up by the roots and transported within the plant through specialized tissue (the veins of the plant) called the xylem. Most water taken up is lost through the leaves and into the air (≈90%) in a process called transpiration, while smaller amounts are used for photosynthesis (≈1%) or as plant constituent (≈9%). Carbohydrates (sugars and starches) are produced by photosynthesis and distributed within the plant by tissue called the phloem, generally in a downward direction.

Water

Water is one of the most important compounds for growing a crop, yet it is often the most neglected factor. Water serves as a medium in which chemical processes, such as ion uptake and photosynthesis, take place and acts as a coolant through transpiration for both the crop and its environment. The two most important aspects that must be considered relate to quantity and quality of the water needed to produce a crop.

Uptake

The passive uptake of water through the roots of the plant begins with water transpiration from the leaves through openings called stomata. Water vapour moves from areas of high water vapour pressure in the leaves through the stomata to areas of lower pressure outside the plant. Under conditions of high humidity, less water vapour will be lost from the plant because there is a higher water vapour pressure outside the plant than there is when the humidity is lower. This process begins a chain reaction whereby water is drawn up through the xylem to replace that lost through the leaves. Consequently, water in the soil is drawn in through the root hairs following the same gradient. Water uptake into the roots is also dependent on the moisture levels in the soil and the salt concentration in the soil. All three factors—relative humidity in the air, soil moisture, and salt concentration in the soil solution—can affect water uptake.

Quantity

Water requirements for a crop can vary between 0.1 and 7 L of water per square meter of greenhouse per day, of which 90% is required during the daylight hours. This varies according to plant species, plant size, relative humidity, solar radiation, temperature/heating and rate of ventilation. When sizing irrigation equipment (lines, pumps, nozzles) it is recommended that 1 L/m^2/hour be used as a base requirement. The total annual water requirement for a year-round greenhouse operation in a recirculating system exceeds the Ontario annual precipitation by about 25–35%. This means that rainwater collected from the greenhouse roof alone does not fulfill the annual requirements. Water is particularly critical during the summer.

Quality

In addition to having a plentiful and reliable supply of water, the quality must also meet certain criteria, the most important of which are:

- the concentration of suspended particulates, which can affect irrigation equipment or foliage residue with overhead watering.
- the amount of dissolved chemicals, which can impact on plant growth and nutrition.

It is the second of these (the amount of dissolved chemicals) that provides growers with most concern. The specific requirements for water quality depend on several factors:

- What growing/irrigation system will be used? Is it a once-through or recirculating top irrigation system (soil or substrate), or a recirculating system (sub-irrigation system for potted plants, or nutrient film technique or recirculation using sand or substrate)?
- Water quality standards must be higher for a recirculating system as certain ions may accumulate in

the solution, and there is the increased potential for spread of root diseases.

- Is there good drainage for excess water in case the need for leaching arises?
- Which crops are to be grown and do they have any specific needs or sensitivities for particular elements such as boron, fluoride, zinc, etc.?

In situations where crops are being irrigated from the top with no recirculation, a simple water analysis will suffice to determine water quality. This analysis includes electrical conductivity (EC), hydrogen ion concentration (pH), sodium (Na^+), chlorides (Cl^-), and sulphates (SO_4^{2-}). For sub-irrigation or in recirculating systems, a complete water analysis including bicarbonates (HCO_3) and the micronutrients iron (Fe^{3+}), boron (B), zinc (Zn^{2+}), manganese (Mn^{2+}), and copper (Cu^{2+}) is recommended.

EC

The EC is a measurement of the total amount of ions (or ionic charge) in the solution. The total ionic charge is measured by an electrical conductivity (EC) meter, and is often referred to as the total soluble salts. A high number of ionic charges results in a high EC. The EC measures the conductivity of a solution by means of two electrodes, each 1 cm² in size and 1 cm apart. It is expressed in millimhos/cm (mmho/cm) or milli-Siemens/cm (mS/cm or dS/m) at the standard temperature of 25°C. Another way of referring to soluble salts is by the ionic concentration in equivalent weight per litre (eq/L or meq/L), which represents the amount of charge provided by all ions in solution.

To convert between eq/L and mS/cm:

- 1 meq/L ≈ 0.055 mS/cm ≈ 55µS/cm
- 1 mS/cm = 1000 µS/cm ≈ 18.2 meq/L

where the m represents milli (0.001 or 1 part per thousand) and the µ represents micro (0.000001 or 1 part per million).

It is important to remember that that an EC meter does not measure the concentration of specific ions but the total sum of all ionic charges. A higher value indicates a higher concentration of ions in solution, and the more difficult it is for the plant to absorb water. The EC meter should be calibrated on a regular basis with a standard solution with a known EC. For example 0.01 M potassium chloride (KCl), made by dissolving 0.74 g KCl in 1 L water, has an EC of 1.4 mS/cm at 25°C. With repeated use of the meter, the EC reading becomes lower as the electrodes oxidize. The electrodes can be cleaned by placing them in an acid solution (pH 1.0–2.0) overnight. If the EC meter is not temperature-corrected to 25°C, then the measured values should be increased by 2% for each 1°C less than 25°C.

A general quality classification for water is given below. It is a modified version of the Dutch and Ohio recommendations. It should be noted that all conditions have to be met in order to place a sample in a certain class.

TABLE 2–1. Classification of Water Quality Based on Electrical Conductivity (EC) and Certain Specifications.

Class	E.C. (mS/cm)	Na^+ (ppm)	Cl^- (ppm)	SO_4^{2-} (ppm)
1	<0.5	<30	<50	<100
2	0.5–1.0	30–60	50–100	100–200
3	1.0–1.5	60–90	100–150	200–300

Water quality of Class 1 is good for all purposes. Most water obtained from Lakes Erie and Ontario falls within this category. Water belonging to Class 2 should be used only in substrate and soil culture where adequate leaching can take place. It is unsuitable for nutrient film technique and salt-sensitive crops grown in sub-irrigation systems. Class 3 is not recommended for salt-sensitive crops (e.g., primula, African violet, gloxinia), crops grown in a limited root volume, or recirculating systems. If the salt level exceeds 1.5 mS/cm it is considered marginally suitable for greenhouse irrigation. In some cases crops can be grown, but yields may be reduced as a result. The toxic concentration for sodium (Na^+) is lower than that for chlorides (Cl^-) due to the fact that sodium has a tendency to be absorbed in soil or humus particles and accumulates in the soil. It may interfere with the uptake of potassium, calcium, and magnesium. Chlorides have less tendency to accumulate due to their negative charge. Some crops are chloride sensitive (cucumber, azalea). It should be noted that sodium levels in most areas in Ontario are low while sulphates are relatively high due to the presence of gypsum in the aquifers. Most crops do not require more than 100 ppm of sulphates (=33 ppm elemental sulphur) to meet their nutritional requirement for sulphur.

Why measure EC?

Even though the EC measurement does not indicate which nutrients are present or in what quantity, it does provide an overall level of the nutrient status of the solution. A high EC means that there are many dissolved ions in solution, which makes it difficult for the plant roots to take up water. In severe cases roots may lose water under such conditions, leading to root damage or death. This generally occurs when there is insufficient leaching, plants are overfertilized, or the irrigation water is of poor quality (high EC). Foliage may be dark green and small, and plants may wilt even though the media is not dry.

A low EC means that there are few dissolved ions in solution, and it is easier for roots to take up water. The plants will be more lush and may be underfertilized since there are not as many nutrients available. However, root growth will be encouraged. Low EC often leads to a deficiency of one of the macro-elements (nitrogen, phosphorus, potassium, calcium, magnesium, or sulphur).

How to measure EC of the growing medium

There are four main ways to measure EC in a substrate sample:

- Saturated media extraction (SME) method
- Spurway (1 soil:2 water) dilution technique
- Pour-through
- Squeeze method

The SME and Spurway techniques involve removing a sample of substrate from the root zone and taking measurements on the filtrate. These are the most commonly used techniques in an analytical laboratory. Across North America, the SME is the most common greenhouse media extraction procedure used by university and private laboratories. The EC using SME is usually about 2.5 times greater than that measured by the 1:2 Spurway technique.

The pour-through technique is done by pouring distilled or deionized water in at the top of the pot and collecting the first 50 mL of the leachate for EC and pH readings. This method is rapid and very useful for inhouse monitoring, but the water has to be poured evenly and consistently over the soil surface. Another drawback is that high values can be found in some older (especially sub-irrigated) pots due to high salts at the top of the growing medium.

Another option for in-house monitoring is the squeeze technique where plants are removed from the pot, and the lower half of the root ball is squeezed to extract the root zone nutrient solution. This gives a fairly good representation of the actual *in situ* soil solution in contact with active roots. This technique is widely used for monitoring media EC in plug seedling trays. Because of the small sample solution extracted, an EC meter that can be used with only 12 drops of solution must be used.

Interpretation of EC Data

The nutrient demand of a crop depends on the crop development and can be divided into three stages. Initially there is a low demand during seed germination or rooting of cuttings, followed by a high demand during the very active vegetative stage of crop growth, and finally a lower demand as the plants reach maturity. As a general rule, shelf-life is improved by lowering the nutrient levels (and reactivating the root system) towards the end of the crop (e.g., chrysanthemum and poinsettia); however, some crops such as Easter lilies benefit from continued fertilization right up until shipping.

The table below provides suggested EC levels for the actively growing stages of various potted crops using two sampling techniques. For the initial and final growth stages, the EC should be lowered by about 1.0 mS/cm. Five pots should be sampled per representative area per week, and the results averaged and recorded.

- If the EC is too low, additional fertilizer is required to raise it.
- If the EC is too high, leaching with fresh water is needed to lower it. Leaching can also be used for sub-irrigated crops although it is important to determine if the high salts are just in the upper part of the growing medium (which is normal in sub-irrigated crops and doesn't affect the root zone) or are in the root zone. If the root zone has a high EC, sub-irrigating with clear water is appropriate, as the salts are forced upwards.

Crops grown during low light conditions in the autumn and winter require a higher EC than during the summer, because reduced transpiration during this time of the year results in less water (and fertilizer) being taken up. In summer, the high transpiration rate and increased water uptake is often compensated by lower EC values in the nutrient solution.

TABLE 2–2. Relative EC Requirements of Actively Growing Greenhouse Crops Using the SME and Pour-through Methods

Nutrient requirements	SME (mS/cm)	Pour-through (mS/cm)	Crops
Low	0.75–2.0	1.0—2.6	African violet, azalea, begonia, calceolaria, calla, cineraria, cyclamen, geranium, gerbera, gloxinia, impatiens, orchid, primula, streptocarpus
Medium	1.5–3.0	2.0–3.5	Schlumbergera, clerodendrum, dahlia, exacum, zonal geranium, hibiscus, kalanchoe, lilies, rose
High	2.0–3.5	2.6–4.6	Chrysanthemum, poinsettia

pH and Its Role

pH is an inverse measure (or a negative logarithm) of the concentration of hydrogen ions (H^+) in solution. A high number of H^+ results in a low pH, and a low number of H^+ gives a high pH. It is measured on a scale of 1–14 where a pH less than (<) 7.0 is acidic, more than (>) 7.0 is basic, and 7.0 is considered neutral. The higher or lower the pH, the more strongly basic or acidic the solution. Each unit in the pH scale represents a change in the concentration of H^+ by a factor of 10.

Alkalinity

Alkalinity is a measure of the capacity of a product or solution to neutralize hydrogen ions. There are a number of alkaline products used in greenhouse production including dolomitic and calcitic limestone, hydrated lime, various fertilizers, and substrates such as clay and sand. Alkalinity is somewhat connected to pH because it establishes the buffering capacity of a material; e.g., in solution with water it defines how resistant the water is to a change in pH. In Ontario, it is not unusual to have water with more than 200 ppm of bicarbonates, which originates from an underlying limestone base. In this case, the high concentration of bicarbonates neutralizes the hydrogen ions, resulting in a low concentration of H^+, and therefore a high pH.

How to measure pH

There are three main methods of measuring pH:

1. Litmus paper, which is the cheapest (but also the least accurate method), involves dipping the paper into the solution and comparing the colour change in the paper to established colour codes for different pH ranges.
2. pH pens are available that are reasonably priced, quite accurate, and easy to carry around in the greenhouse. They are simply dipped into the solution and a digital read-out is given of the pH.
3. Electrode-type pH meters are the most accurate for measuring pH, but they are also the most expensive and require the most maintenance. A sample can be quickly tested by placing the pH probe directly into the solution. Leave the probe in the sample until the reading stabilizes. Many of the better pH meters have temperature compensation, but the temperature dependence is small (usually within 0.1–0.3 units). Rinse the probe between samples. Calibration is very important. The probes are not as stable as the probes of EC meters. Probes should be calibrated at least weekly using standard pH solutions of 4.0 and 7.0 pH. Probes should be kept clean and stored in solution, and replaced more frequently than EC probes.

The pH of the substrate can be checked using the slurry or solution collected for measuring EC.

Why measure pH?

Although hydrogen ions themselves are not considered a nutrient element, pH does influence the solubility and thus the availability of other nutrients (especially micronutrients). For instance, most positive ions (cations) such as iron, manganese, and calcium as well as phosphates, are more soluble at lower pH (and can be tied up in unavailable forms at higher pHs), while molybdenum is more available at a higher pH. The pH also directly influences the colonization of certain pathogens in the soil that maybe harmful to plants.

Different crops have different sensitivities to pH based on their sensitivities to some of these micronutrients (or lack of them). For example, pH <5.5 can result in the accumulation and toxicity of nutrients such as manganese and iron in marigold and geranium. In other plants such as azalea and hydrangea, a low pH is required to ensure maximum uptake of iron and aluminum essential for proper leaf and bloom colour. A pH of 5.5–6.5 is considered optimal for most crops grown in soilless mixes with more than 50% organic matter.

The following table lists crops with more specific optimal pH ranges.

TABLE 2–3. Optimal pH Ranges for Various Crops

Crop	Optimal range
Marigold, geranium, celosia, Easter lily	6.0–6.6 (+/- 0.2)
Pansy, petunia, snapdragon, vinca, salvia, blue hydrangea	5.4–5.8
Azalea	4.8–5.4

Other factors that also need to be considered include the following:

- It is desirable for crops sensitive to low pH, like geranium and marigold, to have slightly higher pH.
- Crops like pot chrysanthemum, which tend to force the pH up over time, should have lower pH early in the crop.
- The stage of crop growth (age) should be considered. At flowering, pH is often not as critical as it is earlier in the crop.
- The fertilizers being used also have an impact on the pH of both the nutrient solution and media. Know whether the complete fertilizer you are using is basic or acidic in reaction.

Because of the bicarbonate content and the use of soilless media, most growers now adjust the pH of their irrigation water using either phosphoric, nitric, or sulphuric acid.

Adjusting the pH

Irrigation Water

For many smaller growers, injecting acid through their fertilizer injector is the method of choice. Be sure that the injector is designed to handle acids. For other growers, installation of in-line pH probes controlling an acid pump is the method of choice. Both methods work well. Rates of acid required are shown in the table below.

TABLE 2–4. Volume of Acid Required to Neutralize 61 ppm HCO_3^- (1 mmol/L) per 100,000 L of water

Acid	Spec. Gravity (kg/L)	Volume of Acid (L)
Phosphoric (85%)	1.7	6.8
Nitric (67%)	1.5	6.6
Sulphuric (93%)	1.8	2.8

It is usually desirable to leave about 60 ppm bicarbonates in the irrigation water as a buffer against change. If the initial level of bicarbonates is 240 ppm, then approx. 180 ppm needs to be neutralized; in this case, three times as much acid as is indicated in the above table would be needed.

Media

If the pH is too low, consider the following steps:

For soilless mixes

1. Discontinue acidifying water supply.
2. Shift to a basic-reaction fertilizer (high in nitrate nitrogen).
3. Use potassium bicarbonate (100–200 kg/1000 L) of stock @1:100 dilution, with an EC in the final solution of about 1.5–2.0 ms/cm.
4. If limestone is used, the amount to be added depends on the type and ratio of the ingredients. Sphagnum peat moss (pH 3.5–4.5) and bark (pH 4.0) are acidic. The amount of limestone needed to neutralize sphagnum moss from a pH 3.5 to a pH 5.5 is about 6–7 kg/m^3 of loose peat moss. Alkaline materials are often the baked-clay types such as Turface, Haydite, and Crackpot or sand. The addition of clay additives with a high pH should reduce the amount of limestone needed. A check of the pH should be made after preparation but before planting. The pH of newly prepared moist media will continue to rise for about 10 days.

For soil beds

1. To increase the pH by 1 unit, use 4.8 kg limestone per 100 m^2.
2. For a soil with a higher clay content or a higher organic matter content, increase the recommended amount by about 25%.
3. Two to three weeks after application, check the soil pH to see if the desired pH level has been attained. Note that the finer the limestone, the quicker its reaction with the soil.
4. The rate of pH change is also affected by temperature, moisture, and aeration conditions of the soil. Changes will occur most rapidly when soils or soilless media are warm, moist, and well-aerated.
5. The use of hydrated lime in greenhouses has some severe drawbacks, as it reacts very quickly and reactively. Proper distribution of the material throughout the soil mixture is difficult and, consequently, the use of this material is very limited.

If the media pH is too high, it can be difficult to lower, but the following steps will help:

1. Increasing the acidity of the irrigation water. Usually there is no harm in lowering pH of the nutrient solution to 5.2–5.4.
2. Discontinue using basic-reacting fertilizers like calcium nitrate.
3. Instead use more ammonium-based fertilizers.
4. Drench with iron sulphate @ 5 kg/1000 L of water. Be sure to lightly wash the foliage immediately after to avoid burning.
5. Use elemental sulphur @ 15 kg /1000 L of water.

TABLE 2–5. Adjusting pH for Soilbeds

Materials	kg/100 m^2 to lower pH 0.5–1 Unit[1]	Rate of pH Change
Finely Ground Sulfur	2.5 kg	Slow
Aluminum Sulfate	15 kg	Rapid
Iron Sulfate	15 kg	Moderate

[1] Rates are for light to medium soils. For heavier soils with more organic matter, increase rate by one-third. The rates per m^3 of potting soils are one-half of the above recommended rates.

Soilless growing media

Soilless mixes have replaced soil-based mixes over the past 10–20 years. Whether the mix is used for plant growing, propagation, container growing, bench crops, or even cut flowers, there has been a gradual reduction in the use of actual soil *and* an increase in the use of artificial ingredients. Soilless mixes are available already prepared in bags or bales, in bulk, or as separate ingredients that can be blended together.

Why use soilless mixes?

Soilless mixes offer several advantages over a conventional soil mix:

- Uniformity and consistency from one batch to the next.
- Most are considered to be essentially disease- and insect-free, thereby reducing the need for costly pasteurization.
- There is less likelihood of contamination from herbicide residues, which can occur with mixes containing field soil.
- The ingredients of a soilless mix are readily available and most are much lighter than soil.
- Soilless mixes have greater pore space and higher water-holding capacity than soil mixes.

Functions of a good growing medium

A growing medium should perform four basic functions:

1. Provide an anchor system for the plant roots.
2. Store water for plant-root absorption.
3. Provide a buffer for nutrients absorbed by the roots.
4. Provide oxygen (air space) for root respiration.

Common ingredients

Sphagnum peat moss

This is one of the most widely used materials, due to its physical characteristics and price. Sphagnum moss is a primitive plant that grows in bogs. While the upper part of the plant continues to grow, the bottom part dies, decomposing into peat. The moss leaves consist of living cells that may or may not contain chlorophyll, as well as dead "sphagnum" cells, which contain water and air. The dead sphagnum cells are unique in that they can absorb and conduct water. These cells have lignified walls that prevent their collapse when drying out. Water in these cells is absorbed by capillary action. Because the leaf and stem cells are surface active and are generally negatively charged, they can adsorb nutrients (e.g., positive ions) in a similar way to clay particles. Nutrients can also be absorbed in the sphagnum cells as dissolved ions in water.

A sphagnum peat bog has a top, middle, and bottom. Because of the way sphagnum grows, the older mosses will be at the bottom, and are the most decomposed. These are darkest in colour and finest in particle size. The top layers are more yellowish, and coarser in structure. The coarser the peat, the lower the bulk density, the greater the air space, and the smaller the water-holding capacity (by volume).

The method of peat moss harvesting plays an important role in the particle size distribution. There are two ways in which peat is harvested—the vacuum method and the block procedure. The vacuum harvesting method involves loosening the surface, air drying, and vacuuming the top surface of the bog. Block harvesting involves digging the peat in chunks and letting them dry overwinter. The following spring the chunks are loosened and packaged. Block-harvested peat is coarser than vacuum-harvested.

Cation exchange capacity (CEC) gives an indication of how many cations can be adsorbed per unit weight and how their supply to plants will be regulated. With its high CEC, peat moss is well suited as a nutrient reserve and buffering agent. Pure peat moss, however, contains very few nutrients as determined by the electrical conductivity of the saturated medium (EC< 0.5 mS/cm).

Due to its naturally low pH (3.5–4.5), peat moss is considered to be free of active pathogenic diseases, although dormant pathogenic spores or weed seeds may be present. Some people claim that peat moss suppresses fungal diseases.

The low cost on a volume basis makes peat moss one of the more desirable mix ingredients. Normally, commercial and grower-made mixes today consist of 50%–100% sphagnum peat moss. The sphagnum peat mosses available today in Ontario are generally sold in a compressed form and will expand by 40%–60% depending on compression level.

Vermiculite

This is a mica-like material that has been expanded under high temperature (900°C). This material can be compared to clay particles except that it has lost its swelling and shrinkage capabilities. It has a high cation exchange capacity (CEC), similar to peat moss on a weight basis, and contains considerable potassium and magnesium ions. It improves the air porosity, provides structure to the medium (less shrinkage), and makes rewetting of a mix easier. Water can also be absorbed internally between the platelets. Acidity is near neutral, and bulk density is 80–100 kg/m^3. Three grades are normally available—coarse, fine, and regular. It is mined in Washington and South Africa.

Perlite

This is an aluminum-silicate of volcanic origin that has been heated to about 1000°C. It is similar to popcorn as it consists of a number of closed, air-filled cells. Water is absorbed primarily on the outer surface and to a lesser degree within the particle. This inert material is primarily added to the mix to improve aeration and drainage as well as structural stability. The pH is about 7.0 while the CEC is negligible. Bulk density is similar to that of vermiculite or peat moss, about 100 kg/m^3.

Rockwool

This product is manufactured by spinning molten rock. There are two forms available, namely, the bonded product and the granulated material. The base material is sterile and does not contain any CEC or an appreciable level of soluble salts. The bonded product is cut into slabs 15 or 20 cm wide, 7.5–10 cm thick, and 90–200 cm long, and is used primarily for the production of greenhouse vegetables (tomatoes, cucumbers, and peppers) or cut flowers (rose, gerbera). It can be purchased with or without a plastic sleeve. Slabs contain a binder for stability and a wetting agent to facilitate water absorption and distribution. The granulated material comes in three sizes (fine, medium, and coarse) and does not contain any binder and/or wetting agent. Granulated rockwool is added to a mix to increase pore space and water-holding capacity and for easier rewetting if the medium is allowed to dry out.

Rockwool can also be manufactured from steel slag. This material, often referred to as mineral wool, generally has a relatively high pH (7–8) and higher levels of micronutrients compared to rockwool.

Polystyrene chips

This is a waste product created from polystyrene bead boards. The material is inert, with negligible CEC and near-neutral pH. Its role in a media is similar to perlite except that there is no surface absorption of water. Bulk density is 25 kg/m^3, and it cannot be pasteurized due to shrinkage. It has a tendency to float to the surface of the pot and can be a nuisance with recirculating sub-irrigation systems. Soil-mix uniformity can be of concern because of its tendency to separate from the rest of the mixture.

Turface®

This is a baked clay with neutral reaction (pH 7.0). Because the bulk density is 750 kg/m^3 and the CEC is high for regular grade, the material is used to increase the weight and the buffering capabilities of the mix. The CEC is about the same as vermiculite.

Haydite®

This is a shale expanded by treating to 1200°C. Bulk density is about 800 kg/m^3 depending on size and grade. It has a high pH (8.5–9.5) and can be obtained in several grades according to particle size. The neutralizing capacity of this material has to be considered when used in appreciable quantities.

Gro-Bark®

Composted barks may suppress toxic substances and plant pathogens. Hardwood barks are generally composted for three months, while softwood barks take about 1½ months to compost. Nitrogen is generally added at 1 kg or 0.5 kg/m^3 for hardwood and softwood bark, respectively, before composting. Gro-Bark, a commercially available product, is a blend of aged pine bark and sawdust that has been naturally composted for 10 to 40 years. It ranges in pH from 4.5 to 6.5 and is low in salts. Available in bulk only, it is often used as bedding in walkways, as an amendment for containerized nursery material, or as a substitute for peat moss.

Grow-Rich®

Grow-Rich is a composted material that is produced from papermill sludge and other organic materials (animal manures, sawdust, and corncobs). The bulk density is about 400 kg/m^3, while typical particle size ranges from 3–6 mm. The pH is between 5.5 and 6.5, and soluble salts are near 1.5–2.0 mS/cm, using the saturated-medium extraction method. As a consequence, the final potting mix should not contain more than 25% of this material.

Worm Castings

Worm castings are a by-product of worm raising. They are high in organic content and stable in structure. The pH is 6.0–7.5 while soluble salts are between 1.0–1.5 mS/cm. Bulk density is about 200 kg/m^3. It should be used sparingly in a mix (less than 25% of the volume) to provide structural stability and more pore space to the media. It is somewhat hydrophobic in nature and quite expensive.

Sand

Although technically a type of soil, sand is quite often incorporated into soilless mixes to provide weight. It is about 15 times heavier than the other major components (peat, perlite, and vermiculite). Drawbacks with sand include:

- its grinding action on the other ingredients if mixed too long, causing a reduction in air space.
- its potential for containing plant pathogens, therefore requiring pasteurization with possible impact on medium pH over time.

However, sand (similar to soil) improves wettability of the mix. Depending on its source in Ontario, sand often has a high pH (about 8.5), indicating the presence of free calcium carbonates. When used, its neutralizing capacity should be considered.

Physical Characteristics of a Soilless Mix

A soilless (or soil) mix has three major components—air, solids, and water. The air space is needed to provide oxygen for root respiration and to allow nitrification and some microbial activity. The air space in a mix complements the water portion, since air replaces the water absorbed by the plant roots. The air/water ratio in a mix is determined by the particle size of the solids. After watering a coarse mix, air will enter the mix quicker than it will in finer mixes but may not be distributed uniformly. Therefore, a coarse mix has relatively more air and less water-filled pore space than a fine one. A lack of air space can be a problem when using a fine-textured mix during the lower light periods of the year. Another factor that affects the air:water ratio is the height of the pot; the taller the pot the greater the air:water ratio.

After watering, a soilless mix may have up to 75% of the total space filled by water, with the remainder taken up by solids (5–10%) and air (15–20%). In a soil mix, solids compose 50% of the space, with the balance divided between air and water. This basic difference between a soil and a soilless mix therefore necessitates a change in crop management. The bulk density of most soilless mixes is about 100–200 kg/m^2. Shrinkage of the mix is of some concern due to the changing physical properties, but also due to the volume of the medium required for a given pot size. Peat moss and rockwool will both shrink. The addition of structural components such as perlite or vermiculite, or compressing the mix when filling the pots, helps to alleviate medium shrinkage.

Preparing a Soilless Mix

There are several considerations that must be taken into account when preparing a soilless mix:

- water-holding capacity
- air porosity
- nutrient availability
- buffering capacity
- weight
- price

TABLE 2–6. Example of a Soilless Mix with Amendments

Ingredients	Percent (by volume)
Sphagnum peat moss	50–60%
Vermiculite, perlite, polystyrene, bark, granulated rockwool	20–40%
Turface®, Haydite®, sand	10–20%

Amendments	Rate/m^3 of mix*
Limestone (fine grade, dolomitic)	3.5 kg
Superphosphate	1.5 kg
Potassium nitrate (12-0-44) or ammonium nitrate (34-0-0)	1.0/0.4 kg
Trace elements	0.25–0.5 kg
Wetting agent	100 mL

The major component in most soilless mixes is sphagnum peat moss due to its excellent growing properties. The quality of the peat moss is important as it is the principal ingredient. A coarse peat provides more natural air space and could be used at a higher percentage in the mix. A finer mix, with less air space, should constitute less of the final mix. For aeration purposes and to give structure to the mix (with less shrinkage), one or a combination of the following ingredients should be used: vermiculite, perlite, granulated rockwool, or polystyrene chips. Vermiculite and rockwool are excellent materials, as they increase water-holding capacity as well as the rewetting characteristics. The third ingredient (Turface®, Haydite® or sand) is added for weight, buffering capacity, and/or pore space.

The limestone (3.5 kg/m^3 of mix) is added to bring the pH of the mixture to an acceptable level (based on a mix containing 50% peat moss). The amount of limestone indicated does not take into account any neutralizing effects from the other ingredients (e.g., Haydite®, sand) or the acidifying effect of some fertilizers (ammonium nitrate). It may take one week after mix preparation and initial wetting before the pH is stabilized.

When calcitic limestone is used, supply magnesium in the form of Epsom salts (0.5 kg/m^3). Superphosphate is added for phosphorus, sulphur, and calcium. If nitrogen and/or potassium are also to be added, use potassium nitrate (12-0-44) at 0.5–1.0 kg/m^3, or ammonium nitrate (34-0-0) at 0.3–0.5 kg/m^3. The nitrogen addition would amount to about 0.25–0.50g nitrogen per 15-cm pot. In some instances, calcium nitrate may be used as the nitrogen source at 0.5 kg/m^3. The trace elements Fe, Cu, B, Zn, and Mn can be added using Nutritrace. As a wetting agent, a non-ionic reagent such as Aqua-Grow® or Agral-90 is suitable. The wetting agent should be dissolved in warm water and sprayed over the mix for uniform distribution. Sometimes a combination of trace elements and wetting agent is available in granular form. For convenience purposes, many growers have their amendments premixed by their fertilizer supplier. Most ingredients can be mixed when dry. Screw-turn and tumbler-type mechanical mixers can be used, but pulverization of components should be prevented by minimizing mixing time. Water can be added when the ingredients are being mixed.

Chemical Characteristics of Mixes

After a mix is prepared, always check the soluble salts (EC) and pH. The EC gives an indication of the nutrient status by measuring the conductivity of the solution, while the pH plays a major role in determining the nutrient availability. The optimal pH for organic soilless mixes is around 5.5 (±0.5). This contrasts with the recommendation of pH 6.5 for soil mixes. In the peat-like mixes, a high pH (over 6.5) can cause iron, manganese, boron, copper, zinc, and phosphorus deficiencies, while a pH of 5.0 to 5.5 can cause molybdenum deficiency (especially in poinsettia). Addition of ammonium nitrate at 400 g/m^3 may reduce the pH by about 0.5.

Ready-made Mixes

Most commercially prepared mixes have been tested and will perform well when managed properly. When comparing prices between commercial mixes and mixing your own, the costs of materials, mixing, equipment, storage space, and labour cost for making the mixes are important and should be considered. Smaller operations often use ready-made mixes. Some manufacturers will blend and deliver mixes to growers' specifications. The ready-made mixes usually follow the above outline of ingredients, although the third major ingredient (Turface® or sand) is usually omitted. Most ready-made mixes have a pH of 5.5–6.0 and an EC of 1.2–1.8 mS/cm using the saturated-media extraction method, while the water-holding capacity is about 70% on a volume basis after a 15-cm diameter pot is totally saturated and allowed to drain.

Composts

Some growers may choose to use composted material as part of their soilless mix. Composts may contain antagonistic fungi and bacteria (to suppress plant diseases) as well as other beneficial microorganisms (such as nitrifying bacteria). Composts made from assortments of organic by-products are available in bulk from various suppliers at relatively low costs. These may be used successfully as amendments, but it is advisable to check pH and soluble salts before use.

Common Problems with Soilless Mixes

1. Mixing the ingredients of a soilless mix for too long a period grinds the particles together, breaking

them down, and thereby destroying medium structure. A general guideline is 3–5 minutes at 12–14 rpm.

2. Rewetting a soilless mix after it has dried out is difficult, but not impossible. It can be accomplished by several light waterings or mist applications. A wetting agent can also be added to the water at approximately 1 mL/L of warm water. Normally, the wetting agent is added when mixing the ingredients. Addition of granulated rockwool or vermiculite improves the rate of rewetting after severe drying out. Excessive levels of wetting agent incorporated into the medium (e.g., 2–3 times the recommended rate), can result in the development of only a few long stringy roots or a failure of the roots to penetrate the medium. This may cause overall stunting of sensitive species, including impatiens, begonia, and cucumber.
3. Algal growth on the surface may restrict seedling emergence, reduce water penetration, and/or serve as a food source for fungus gnats. Some fungicides may reduce algal growth; also, as the plants grow, reduced light levels on the surface will restrict development of algae. Agribrom added to the irrigation water at 5–10 ppm of residual bromine will help to control/prevent algal growth. Algae-free irrigation water reduces this problem as well.
4. Optimal nutrient levels are usually higher than in a soil mix. Therefore, it is important to keep the crop well fertilized. Soluble-salts readings can safely be about twice as high as those in a soil mix.
5. Symptoms of magnesium deficiency show up quickly on crops like tomatoes and chrysanthemums. This is because most conventional water-soluble "complete" fertilizers do not contain magnesium. Preplant incorporation or separate feedings of Epsom salts (magnesium sulphate) or magnesium nitrate will help control this situation.

The Role of Nutrients in Plant Growth

Plant nutrients can be divided (depending on the quantity required of each by the plant) into macro- and micro-nutrients (see table below). Also shown is the form in which the element is taken up by the plant and its mobility within the plant (M = mobile, I = immobile, N/A = not available).

TABLE 2–7. Macro- and Micronutrients in Plants

Elements	Form	Mobility
Macronutrients		
Carbon (C)	Carbon dioxide (CO_2)	M
Hydrogen (H)	Water (H_2O)	M
Oxygen (O)	CO_2, H_2O	M
Nitrogen (N)	Ammonium (NH_4^+), Nitrate (NO_3)	M
Phosphorus (P)	Dihydrogen phosphate ($H_2PO_4^-$)	M
Potassium (K)	Potassium ions (K^+)	M
Calcium (Ca)	Calcium ions (Ca^{2+})	I
Magnesium (Mg)	Magnesium ions (Mg^{2+})	M
Sulphur (S)	Sulphate (SO_4^{2-}), Sulphur dioxide (SO_2)	M
Sodium (Na)	Sodium ions (Na^+)	N/A
Silicon (Si)	H_4SiO_4	N/A
Micronutrients		
Iron (Fe)	Ferrous ions (Fe^{2+}), Ferric ions (Fe^{3+})	I
Manganese (Mn)	Manganese ions (Mn^{2+})	I
Copper (Cu)	Copper ions (Cu^{2+})	I
Zinc (Zn)	Zinc ions (Zn^{2+})	I
Molybdenum (Mo)	Molybdate ions (MoO_4^{2-})	M
Boron (B)	Boric acid (H_3BO_3)	I
Chlorine (Cl)	Chloride ions (Cl^-)	M
Aluminum (Al)	Aluminum ions (Al^{3+})	M

There are two main factors affecting the mineral content of a plant. The first is genetically determined and accounts for the fact that N and K content of many plants (46%) is about 10 times higher than that of P and Mg, which are in turn 100–1000x higher than most micronutrients.

The second is the availability of nutrients in the growing medium and the ability of the plant to absorb them. In practice, this is the only factor we can influence. Up to a certain level, the nutrient content of a given plant increases with a higher content of nutrients in the growing medium. Beyond this optimum level, no benefit can be expected from further increase in availability.

Uptake and Translocation of Nutrients

Macronutrients

In general, all macronutrients except calcium are mobile within the plant. Mobile nutrients can move in both the xylem and phloem and will be translocated to where they are most needed, usually developing shoots, flowers, or bracts.

- Carbon—is taken up primarily in the form of CO_2 through the stomata in the leaves. It is then transformed into organic material through the process of photosynthesis. To a lesser extent it may also be taken up in the bicarbonate form (HCO_3^-) from the nutrient solution.
- Hydrogen—water is the major supplier of H^+ through absorption by the root hairs.
- Oxygen—is taken up in CO_2 during daylight, and in water through the roots.
- Nitrogen—both NH_4^+ and NO_3^- forms can be absorbed by the roots and metabolized by the plants. The rate of NO_3^- uptake is usually greater than that of NH_4^+. However, this depends strongly on pH. NH_4^+ uptake occurs best in a neutral medium and decreases with a lower pH. The reverse is true for NO_3^-. High carbohydrate levels in the plant (e.g., during summer) favour uptake of NH_4^+. Within the xylem, nitrogen is transported as nitrate and amino acids.
- Phosphorus—the majority of P is actively taken up (from very low concentrations in the soil to higher levels in the xylem) as $H_2PO_4^-$.
- Potassium—is taken up as K^+, often actively, and is mobile within the plant.
- Calcium—is absorbed passively (from higher concentrations in the soil to lower concentrations in the plant) as Ca^{2+}. Calcium in the xylem sap is translocated in an upward direction within the transpiration stream, and thus depends on transpiration rate and therefore on humidity (or vapour pressure deficit). Uptake is also favoured by NO_3^-. Within the plant, calcium is not mobile.
- Magnesium—the competitive effects of other cations (e.g., K^+, NH_4^+) are important in determining rate of magnesium uptake. It is taken up passively by the transpiration stream and is mobile in the xylem.
- Sulphur—Plants absorb sulphur mainly in the form of SO_4^{2-}, which may be taken up actively.

Micronutrients

All micronutrients are essentially immobile. They can be absorbed by the roots, moved through the plant in the transpiration stream, and distributed to the various plant parts. However, they cannot be moved out of the various plant tissues and redistributed to other plant parts if needed.

- Iron—uptake is influenced by rate of plant metabolism as well as by the presence of other cations such as manganese (Mn^{++}) and copper (Cu^{2+}). Iron uptake is depressed by high pH, root damage, and high levels of phosphate, manganese, boron, and calcium; it is enhanced by high NH_4^+. Iron is not mobile between plant organs.
- Manganese—uptake is influenced by plant metabolism (similar to iron). Low soil temperatures => low metabolic activity => reduced uptake (e.g., roses in soil beds in winter). Manganese is relatively immobile in the plant. Young plant tissue is usually rich in Mn^{2+}. Manganese availability is enhanced by low pH.
- Copper—similar to iron and manganese. Copper is not very mobile within the plant but can be translocated from older to younger leaves. There are generally very low levels in the plant compared to other micronutrients.
- Zinc—there is some disagreement as to whether zinc uptake is passive or active, although most researchers consider it active. It has a strong interaction with copper. Zinc is not very mobile within plants.
- Molybdenum—there is not a great deal known about molybdenum except that poinsettia is one of a few plant species known to be sensitive to low levels. Molybdenum is important in the function of a major enzyme in plant metabolism.
- Boron—is probably taken up as undisassociated boric acid and follows water flow through the roots. It is immobile within the plant and is concentrated more in older rather than younger leaves. Deficiency is found in the plant tip and toxicity in the older leaves.

Nutrient Analysis

Water

The raw water used for irrigation purposes should contain all the major elements needed for plant nutrition; however, the quantities will have to be adjusted based on a nutrient analysis. Water analysis will also indicate whether the water source is contaminated (*not* by microbial contamination) or whether the concentration of specific ions such fluoride (F^-) or boron (B) may be too high. In addition, the bicarbonate level has to be known so that the required amount of acid can be calculated to obtain a given pH. The table below lists the most common elements involved in plant nutrition and desirable levels in raw water to be used for irrigation.

TABLE 2–8. Maximum Desirable Concentrations of Specific Ions in Raw Water Used for Irrigation Purposes in a Greenhouse Using Soilless Substrates (Rockwool, Oasis, Peat, or Coir)

Element	Maximum desirable (ppm)
Nitrogen (NO_3^-)	5
Phosphorus ($H_2PO_4^-$)	5
Potassium(K^+)	5
Calcium (Ca^{++})	120
Magnesium (Mg^{++})	25
Chloride (Cl^-)	100
Sulphate (SO_4^{2-})	200
Bicarbonate(HCO_3^-)	30–60
Sodium (Na^+)	60
Iron (Fe^{3+} or Fe^{2+})	5
Boron (B)	0.5
Zinc (Zn^{++})	0.5
Manganese (Mn^{++})	1.0
Copper (Cu^{++})	0.2
Aluminum (Al^{3+})	5
Molybdenum (Mo)	0.02
Fluoride (F^-)	1
pH (H^+)	5.0–7.0

General comments regarding the various elements are outlined below:

- N, P, K—Although used for fertilization purposes, the presence of high levels of these elements in the raw water is indicative of contamination.
- Ca^{2+} and Mg^{2+}—The maximum desirable levels described above provide adequate levels of nutrition for most crops. Higher values do not necessarily mean toxicity, but can contribute to the hardness of the water.
- HCO_3^-—Most water sources in southern Ontario contain bicarbonates in excess of the given range. Bicarbonates are not very toxic, but levels of 250+ ppm may create problems for plant growth. High levels provide a high alkalinity (pH), which over time may increase pH levels in the growing medium. The precipitation of calcium and/or magnesium carbonates causing leaf residues and the plugging of emitters is another disadvantage of high carbonate levels. High bicarbonate levels can be neutralized by using nitric, phosphoric, or sulphuric acid (see *Adjusting the pH*).
- Fe^{3+} —Iron in its oxidized form has a low solubility and can therefore easily precipitate as amorphous iron hydroxide, which results in the plugging of emitters. For drip-irrigation systems, levels higher than 0.25 ppm are undesirable.
- B—Boron can be quite toxic to plants and should be carefully controlled in substrate culture (less than 0.5 ppm) or for a recirculating system (less than 0.25 ppm).
- Zn^{2+}—Zinc can be found in water sources that have been in contact with galvanized metal (rainwater from greenhouse roof). Again, the ions may accumulate in recirculating systems.
- Mn^{2+}—Although manganese is not often a problem except under special circumstances (steam pasteurization), it is believed to be toxic at high levels.
- Cu^{2+}—Copper levels may be higher than 0.2 ppm if organic media are used.
- Al^{3+}, Mo, F^-—Aluminum, molybdenum, and fluoride are not commonly found at high concentrations in the water source. However, fluoride can cause serious damages to monocotyledons (lilies, dracaena, spider plant).
- pH—Although hydrogen ions are not considered a nutrient element it is important to include this factor as the availability of most nutrients are pH dependent. For instance, most positively charged ions such as Fe, Mn, Ca, as well as phosphates, are more soluble (and therefore more available to the plant) at low pH, while molybdenum is more available at a higher pH. Most water sources in Ontario have a pH of about 7.5, due to high levels of bicarbonates. Acidification may be required (see *Adjusting the pH*). A pH lower than 5.0 is detrimental to the structure of rockwool slabs.
- See Appendix for laboratories in Ontario that are accredited by OMAFRA to analyze water, nutrient solutions, and media.

Soilless Media

Media testing for nutrient analysis used to be done by mixing water with the soil at a ratio of 1:2 (soil:water). Now the saturated-medium extract method using distilled water is the most widely used, measuring the nutrients directly in the extract. This procedure provides an estimate of what is readily available to the plant in the root zone.

Sampling the Growing Medium

1. Soil—Using a soil probe, take sufficient samples (20) of the area (ground beds) at a depth of between 10–25 cm using a soil probe and bulk the samples. Mix the bulked sample well, take a representative sample (approx. 600 g), put in a plastic bag, and send to an OMAFRA-accredited laboratory approved for Saturated Medium Extraction analysis (see Appendix). Analysis is done on a fee-for-service basis. For seasonal crops, have the soil tested well before the crop is planted. Allow enough time between sending the samples and planting the crop to make nutrient or pH adjustments.
2. Potting media—Only the bottom two-thirds of the potting substrate is sampled (do not include the top layer, particularly when the crop is being sub-irrigated). Several samples (approx. 20) are mixed and a representative sample placed in a plastic bag and sent to the laboratory. Growers should run their own EC and pH tests (between regular sampling for laboratory analysis) by drenching a number of pots with distilled water and measuring the leachate. These results compare fairly closely to the Saturated Medium Extract used by a laboratory (see Interpretation of EC Data) and give a good indication of the total nutrient status, but not of the individual elements. To accurately track nutrient levels in the media, bi-weekly samples should be collected.

For interpretation of results and for adjustments to the growing medium, talk to your greenhouse floriculture specialist.

Foliar

In floriculture, leaf tissue analysis is used primarily as a diagnostic tool to verify deficiency or toxicity symptoms, but can also be used to monitor nutrient levels during the cropping period. Different plant parts contain different levels of nutrients, but analysis of leaf tissue is most commonly used for diagnosing nutrient availability (uptake) in the soil. The mineral content of plants is usually expressed as a percentage on a weight basis for the macro-elements (N, P, K, etc.). For micro-elements (Fe, Mn, Cu, Zn, B, Mo), mineral content may be expressed as milligram per gram (mg/g) or parts per million (ppm) of plant dry matter. Age of the plant parts is important as well. Young plant tissue tends to have higher contents of N, P, and K compared to older tissue, which generally has higher levels of Ca, Mn, Fe, and B. Therefore, harvest the most recently matured leaves of a plant for tissue analysis, if testing regularly to monitor the nutrient status.

Foliar analysis is often a more accurate way to assess the micro-nutrient status of the crop or the fertility program than analyzing the media micro-nutrient levels. Sample the most recently matured leaves from several plants unless indicated otherwise (see table below). Usually 30–50 leaves are sufficient. Avoid leaves with disorders unless that is what you wish to diagnose, in which case take them as a separate sample. Make sure that samples are not contaminated with pesticides or foliar applications of fertilizer. If in doubt, rinse the leaves in distilled water and let them dry before packaging and sending them to the laboratory. Paper bags are generally preferred over plastic so that the leaves do not rot.

(Factors that can affect nutrient content include plant age, position on plant [upper vs. lower leaves], cultivar, season, fertilizer regime, number of days after fertilization, media pH, growth regulator application, presence of disease and temperature. These values are a guide only to the appropriate nutritional status for these plants.)

TABLE 2–9. Tissue Analysis Guidelines

Nutrient	African violet	Alstroemeria	Azalea	Rieger begonia	Wax begonia	Zygocactus (Schlumbergera)	Caladium
Nitrogen (%)	2.2–2.7	3.8–7.6	2.2–2.8	3.4–4.6	4.4–5.2	2.7–3.7	3.6–4.9
Phosphorous (%)	0.2–0.9	0.3–0.7	0.2–0.5	0.4–0.8	0.3–0.4	0.5–0.9	0.4–0.7
Potassium (%)	1.5–6.0	3.7–4.8	0.7–1.6	2.0–3.5	3.4–4.2	6.2–7.1	2.3–4.1
Calcium (%)	0.6–1.7	0.6–1.4	0.2–1.6	0.7–2.4	1.3–2.1	0.7–0.9	1.1–1.6
Magnesium (%)	0.7–1.1	0.2–0.4	0.1–0.6	0.3–0.8	0.6–1.0	1.6–2.2	0.1–0.3
Iron (ppm)	70–320	175–275	50–150	80–390	100–260	105–110	65–90
Manganese (ppm)	35–490	60–90	30–300	35–190	90–355	35–130	110–135
Zinc (ppm)	20–80	35–70	5–60	20–30	50–65	50–65	125–135
Copper (ppm)	5–30	5–15	5–15	5–10	10–15	10–15	5–10
Boron (ppm)	30–200	10–50	15–100	35–130	30–40	65–70	95–145

Nutrient	Calla	Carnation	Chrysanthemum	Cyclamen	Dieffenbachia[1]	Easter lily	Exacum
Nitrogen (%)	2.9–3.0	3.0–5.0	4.0–6.0	2.9–5.0	3.0–4.0	2.4–4.0	3.8–5.3
Phosphorous (%)	0.3–0.4	0.1–0.5	0.2–1.2	0.4–1.0	0.7–1.0	0.1–0.7	0.3–0.7
Potassium (%)	3.9–4.4	2.0–6.0	1.0–10.0	1.2–4.5	6.4–8.2	2.0–5.0	2.3–3.4
Calcium (%)	0.9–1.1	0.6–2.0	0.5–4.6	0.3–1.3	1.9–2.4	0.2–4.0	0.5–0.8
Magnesium (%)	0.3–0.4	0.2–0.6	0.1–1.5	0.4–1.3	0.4–0.8	0.3–2.0	0.4–0.7
Iron (ppm)	95–130	30–150	20–750	150–550	50–300	100–250	55–155
Manganese (ppm)	635–690	30–445	25–375	100–500	50–300	50–250	70–165
Zinc (ppm)	30–45	15–75	5–35	30–100	40–200	30–70	25–85
Copper (ppm)	5–10	5–30	5–50	5–20	3.5–30	5–25	5–75
Boron (ppm)	30–40	20–400	20–200	70–350	10–30	20–50	25–60

Nutrient	Ficus benjamina[1]	Freesia	Fuchsia	Ivy geranium	Regal geranium	Seed geranium	Zonal geranium
Nitrogen (%)	2.0–2.5	2.7–5.6	2.8–4.6	3.4–4.4	3.0–3.2	3.7–4.8	3.8–4.4
Phosphorous (%)	0.2–0.4	0.4–1.2	0.4–0.6	0.4–0.7	0.3–0.6	0.3–0.6	0.3–0.5
Potassium (%)	2.1–2.5	3.1–5.9	2.2–2.5	2.8–4.7	1.1–3.1	3.3–3.9	2.6–3.5
Calcium (%)	1.7–2.5	0.4–1.0	1.6–2.4	0.9–1.4	1.2–2.6	1.2–2.1	1.4–2.0
Magnesium (%)	0.3–0.4	0.3–1.8	0.4–0.7	0.2–0.6	0.3–0.9	0.2–0.4	0.2–0.4
Iron (ppm)	50–200	80–115	95–335	115–270	120–225	120–340	110–580
Manganese (ppm)	25–100	30–540	75–220	40–175	115–475	110–285	270–325
Zinc (ppm)	20–75	40–110	30–45	10–45	35–50	35–60	50–55
Copper (ppm)	5–10	5–130	5–10	5–15	5–10	5–15	5–15
Boron (ppm)	20–40	30–100	25–35	30–280	15–45	35–60	40–50

Nutrient	Gerbera	Gloxinia	Hibiscus	Hydrangea	Common impatiens	Nephrolepis[1]	New Guinea impatiens
Nitrogen (%)	3.3–4.1	3.3–3.8	3.5–4.5	2.0–3.8	4.3–5.3	1.7–2.5	3.3–4.9
Phosphorous (%)	0.3–0.7	0.3–0.5	0.2–0.6	0.3–2.5	0.6–0.8	0.3–0.6	0.3–0.8
Potassium (%)	3.1–3.9	4.5–5.0	2.0–2.9	2.5–6.3	1.8–2.8	2.5–3.9	1.9–2.7
Calcium (%)	0.9–4.2	1.5–2.2	1.9–2.3	0.8–1.5	2.9–3.3	0.9–1.3	1.9–2.7
Magnesium (%)	0.3–2.8	0.4–0.5	0.5–0.7	0.2–0.4	0.6–0.8	0.6–0.7	0.3–0.8
Iron (ppm)	80–130	70–150	60–75	85–115	405–685	30–300	160–890
Manganese (ppm)	65–260	95–170	135–180	100–345	205–490	49–181	140–245
Zinc (ppm)	30–80	20–35	35–50	50–105	65–70	52–149	40–85
Copper (ppm)	5–10	5–20	5–10	5–10	10–15	10–15	5–10
Boron (ppm)	25–50	30–35	20–25	35–50	45–95	20–40	50–60

Nutrient	Kalanchoe	Petunia	Poinsettia	Primula	Rose	Snapdragon	Streptocarpus[1]	Vinca
Nitrogen (%)	2.5–5.0	2.8–5.8	4.0–6.0	2.5–3.3	3.0–5.0	4.0–5.3	2.0–3.5	4.9–5.4
Phosphorous (%)	0.2–0.5	0.5–1.2	0.2–1.0	0.4–0.8	0.2–0.3	0.2–0.6	0.1–0.7	0.4–0.6
Potassium (%)	2.0–4.8	3.5–5.5	1.5–5.0	2.1–4.2	1.8–3.0	2.2–4.1	4.8–5.5	2.9–3.6
Calcium (%)	1.1–4.5	0.6–4.8	0.4–2.0	0.6–1.0	1.0–1.9	0.5–1.4	1.2–1.9	1.4–1.6
Magnesium (%)	0.4–1.0	0.3–1.4	0.2–1.0	0.2–0.4	0.2–0.4	0.5–1.0	0.3–0.5	0.4–0.5
Iron (ppm)	75–200	40–700	100–300	75–155	50–150	70–135	90–260	95–150
Manganese (ppm)	60–250	90–185	45–300	50–80	30–900	60–185	130–300	165–300
Zinc (ppm)	25–80	30–90	25–150	40–45	15–50	30–55	85–130	40–45
Copper (ppm)	5–20	5–45	5–15	5–10	5–25	5–15	15–20	5–10
Boron (ppm)	30–60	20–50	20–200	30–35	20–60	15–40	55–65	25–40

[1] Numbers from *Guide Values for Nutrient Element Contents of Vegetables and Flowers under Glass*, Glasshouse Crops Research Stations, Aalsmeer and Naaldwijk, 1987. (Assembled and updated by R.E. Widmer, University of Minnesota, June 1985. Expanded and updated by J.M. Dole and H.F. Wilkins, University of Minnesota, October 1988, Department of Horticultural Science and Landscape Architecture.)

Recommended portion of plant to sample:

- Chrysanthemum—uppermost leaves from mature flowering shoots.
- Exacum—shoot tips with one pair of mature leaves and all immature leaves
- Rose—uppermost five-leaflet leaf on flowering stems
- Other crops—the most recently mature leaf

It should be remembered that the above guidelines are valid for the use of substrate culture where leaching is possible. More frequent monitoring is suggested for recirculating systems.

Symptoms of Nutrient Deficiency

(Source: Diagnosing Nutrient Disorders in Greenhouse Crops, C. Rosen and J. Erwin, University of Minnesota).

Nutritional Interactions

Nutritional problems in greenhouse crops can be common because of the limited rooting volume of the container and the limited nutrient reserve of the medium in which the crop is being grown. Both the amount of nutrients being supplied and their balance play important roles in producing high-quality container crops. Changing the level of one nutrient in solution can affect the uptake or transport through the plant of another. Although interactions between nutrients can be either positive or negative, it is usually the negative interactions that are most well documented.

Nutrient interactions become a factor in two situations:

1. When the levels of two elements are near the deficiency range, and
2. When one element is supplied in excessive amounts while another is at levels marginally sufficient.

The precise nature of the interaction depends on the nutrients involved and the plant species. It may be the result of precipitation reactions occurring in the soil solution or the result of competition during ion uptake, translocation or metabolic function. In many cases, the mechanism for the interaction may not be completely understood. These antagonistic effects become important when nutrient levels are low.

TABLE 2–10. Some Common Interactions between Nutrients

If excessive in media or tissue:	May cause deficiency of:
Ammonium-N	Calcium
Nitrate-N	Potassium
Phosphorus	Iron, zinc, copper
Potassium	Magnesium, calcium
Calcium	Magnesium, boron
Magnesium	Potassium, calcium
Manganese	Iron
Iron	Manganese
Zinc	Manganese, iron
Copper	Manganese, iron, zinc

Nutrient interactions and proper balance need to be considered in relation to proper supply. Nutrient supply is important because optimum nutrient ratios in the solution or the plant tissue can be achieved even when both elements are in the deficient or toxic range.

Diagnosing Nutrient Disorders

With nutrient disorders, it is important to remember that once visual symptoms are present, marketability of the plants may have already been reduced. Rigorous soil-testing programs should be followed to detect potential problems before they result in crop losses.

In most cases, symptoms of nutritional disorders occur in defined patterns and are specific for each nutrient. Elements that are mobile within the plant generally induce deficiencies on the older (lower) leaves first, while immobile elements induce deficiencies on the younger (upper) leaves. In some cases, pesticide toxicity or disease symptoms may resemble nutrient deficiencies or toxicities.

In addition, symptoms of nutritional disorders are often species or cultivar dependent. Soil and tissue analysis can be used to help confirm whether the symptoms are nutritional.

The following symptoms of nutrient deficiency/toxicity (for nitrogen, phosphorus, potassium, magnesium, and sulphur) generally affect lower leaves first and may progress to younger leaves as the problem becomes more severe.

- **Nitrogen**

Deficiency

1. Leaves turn pale green to yellow
2. Oldest leaves are affected first, but in severe cases, the whole plant may be yellow. Growth is usually stunted.

Excess Ammonium

1. Restriction in plant growth
2. Leaf yellowing
3. Marginal necrosis
4. Death of the growing point
5. High ammonium (generally during the winter months) will interfere with uptake/translocation of potassium, magnesium, and calcium, thereby inducing calcium deficiency and reduced potassium and magnesium content of plant tissue

Excess Nitrate

1. Most plants tolerate high nitrate levels without any symptoms
2. Nitrate enhances phosphorus and potassium uptake
3. Excessive nitrate will induce green vegetative growth and may delay flowering

- **Phosphorus**

Deficiency

1. Leaves appear reddish-purple; lower leaves yellowish
2. Oldest leaves are affected first; necrosis and leaf drop if severe
3. Plant growth is stunted

4. May be induced under high pH (>7.4) or low pH (<5.0) conditions in soilless media

Excess

1. May induce micro-nutrient deficiency symptoms by inhibiting iron, zinc, and copper uptake/translocation, possibly due to precipitation of phosphates.

- **Potassium**

Deficiency

1. Leaves develop grey or tan areas near the margins
2. Oldest leaves are affected first with characteristic scorching of the leaf tips and around the margins
3. In some plants, spotting or chlorosis between the veins may occur
4. Growth may be bushy

Excess

1. May cause salt burn at very high rates
2. If magnesium levels are marginal, excessive potassium will induce magnesium deficiency

- **Magnesium**

Deficiency

1. Older leaves turn yellow between the veins (interveinal chlorosis)
2. In severe cases, younger leaves may be affected and older leaves may develop necrotic spots and then drop off
3. Deficiency can be induced by high potassium levels

Excess

1. Plants can tolerate high levels of magnesium without adverse effects
2. High levels of magnesium can cause deficiencies of potassium and calcium in plant tissue

- **Sulphur**

Deficiency

1. General yellowing of the plant; leaf veins are often yellow
2. Symptoms are similar to nitrogen deficiency

Excess

1. Plants can tolerate high levels of sulphur; however, uptake of molybdenum will be reduced

The following symptoms of nutrient deficiency/toxicity (for calcium, boron, copper, iron, manganese, molybdenum, and zinc) generally affect younger or upper leaves first.

- **Calcium**

Deficiency

1. Growing points of plants may die
2. Youngest leaves are affected first
3. Root tips die, and root growth is slow
4. In some plants, leaf edges or tips are yellow or scorched (often termed leaf-edge or leaf-tip burn)
5. Deficiency can be induced by high levels of ammonium and excessively wet or dry conditions

Excess

1. Plants can tolerate high levels of calcium without adverse effects
2. High levels of calcium can cause lower levels of potassium and magnesium in plant tissue

- **Boron**

Deficiency

1. Usually occurs on younger plant tissue
2. Young leaves are often dark green, thick, and brittle
3. Growing points die, and leaves appear small and distorted, multiple shoot development

Excess

1. Can be highly toxic to some plants
2. Toxicity usually occurs on the oldest leaves as a scorching of the margins

- **Copper**

  Deficiency

  1. Yellowing or dieback of youngest leaves
  2. Sometimes yellowing between the veins
  3. Distortion of the leaves with stunted, strap-like growth
  4. High levels of phosphorus may induce copper deficiency

  Excess

  1. May induce iron deficiency and cause stunted root systems

- **Iron**

  Deficiency

  1. Yellowing between the veins on the youngest leaves, veins remain green (interveinal chlorosis); may turn totally yellow to white with necrosis.
  2. High levels of phosphorus may induce iron deficiency
  3. High pH conditions as well as low soil temperatures will cause iron deficiency

  Excess

  1. Plants can tolerate high levels of iron without adverse effects
  2. Chlorotic spots eventually becoming reddish brown with eventual collapse of affected tissue
  3. High levels may induce magnesium deficiency in some plants

- **Manganese**

  Deficiency

  1. Similar to iron deficiency
  2. Yellowing between the veins of the youngest leaves; usually leaves do not turn white and necrotic
  3. Usually only the main veins remain green causing a fishbone-like appearance
  4. Occurs under high pH conditions and/or low soil temperatures

  Excess

  1. Reddish brown to black spots on lower leaves between veins; leaf yellowing
  2. Occurs under low-pH conditions

- **Molybdenum**

  Deficiency

  1. Young leaves pale, distorted, and narrow; whiptail appearance
  2. Young mature leaves may show interveinal chlorosis and in-rolling of leaf margins; ultimately yellowing tissue becomes necrotic
  3. In some plants, leaf margins may be scorched
  4. Occurs most frequently under low-pH conditions
  5. Phosphorus and magnesium will enhance uptake, while high sulphur will decrease uptake

  Excess

  1. Plants can tolerate high levels of molybdenum without adverse effects

- **Zinc**

  Deficiency

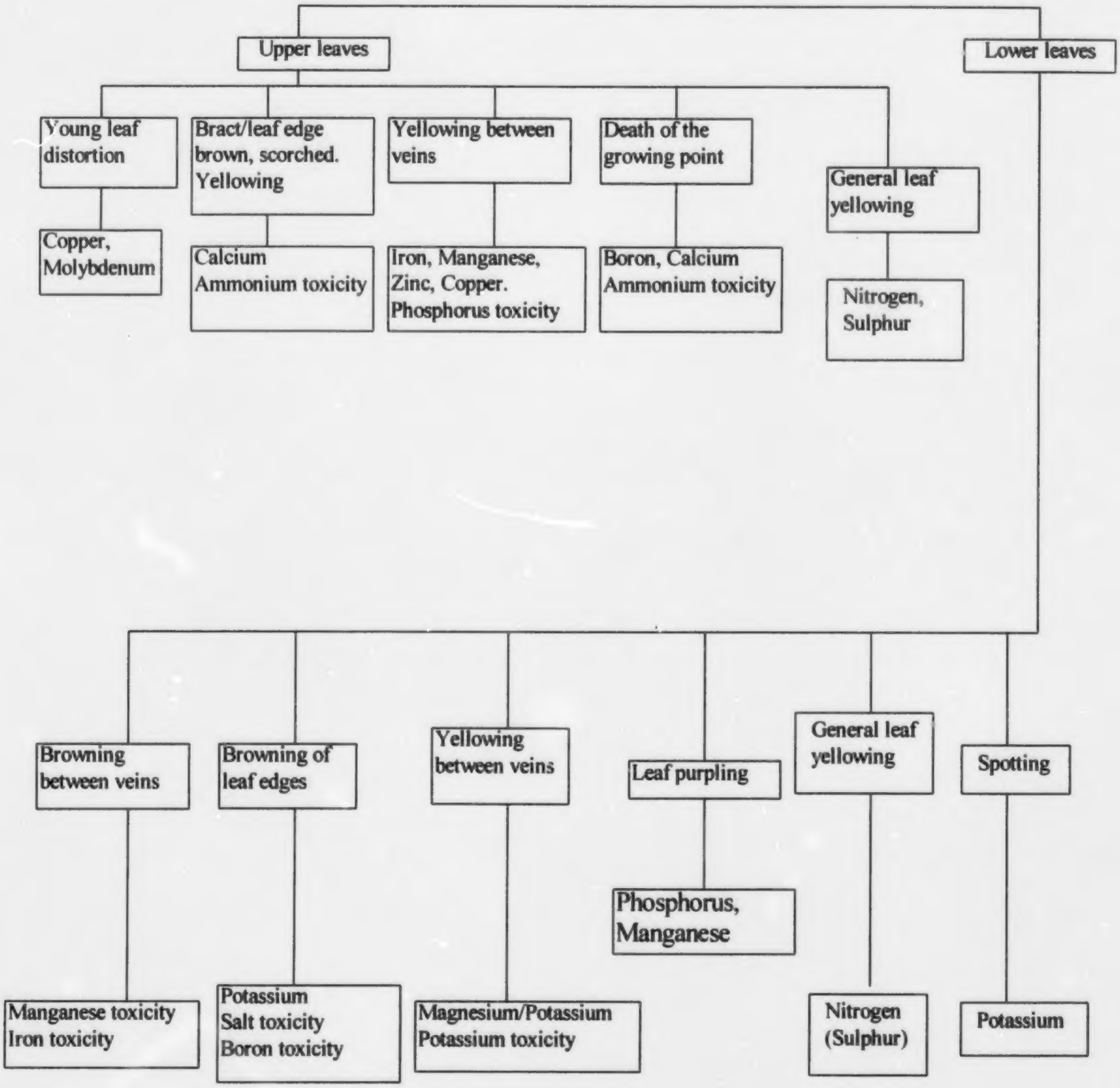
  1. Younger leaves are affected first and may show signs of yellowing between the veins
  2. Other symptoms may include short internodes and rosetting of leaves
  3. High levels of phosphorous may induce zinc deficiency
  4. Occurs under high-pH conditions

  Excess

  1. May depress uptake of phosphorus and iron in some plants
  2. Occurs under low-pH conditions
  3. Results in reduced root growth and leaf expansion

FIGURE 2–1. Key To Determining Nutrient Disorders in Greenhouse Crops

Visual Symptoms[1]


Upper leaves
Lower leaves
Young leaf distortion
Copper, Molybdenum
Bract/leaf edge brown, scorched. Yellowing
Calcium Ammonium toxicity
Yellowing between veins
Iron, Manganese, Zinc, Copper. Phosphorus toxicity
Death of the growing point
Boron, Calcium Ammonium toxicity
General leaf yellowing
Nitrogen, Sulphur
Browning between veins
Manganese toxicity Iron toxicity
Browning of leaf edges
Potassium Salt toxicity Boron toxicity
Yellowing between veins
Magnesium/Potassium Potassium toxicity
Leaf purpling
Phosphorus, Manganese
General leaf yellowing
Nitrogen (Sulphur)
Spotting
Potassium

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1. Symptoms refer to deficiency unless otherwise stated.

3. Integrated Pest Management for Greenhouse Flower Crops

This chapter discusses the tools of integrated pest management (IPM). IPM is a pest control philosophy that uses all available control strategies to maintain pest populations of insects, mites, or disease organisms below an economic injury level. It does not advocate a continuous pesticide spray program to eradicate pests, but promotes the integration of cultural, physical, biological, and chemical control strategies.

The routine spraying of pesticides for insurance purposes is no longer likely to achieve effective control. In recent years, this practice has led to a number of problems, which include resistance, environmental damage, and personal health and safety.

Resistance

With fewer pesticides being developed and registered, and more pesticides becoming ineffective due to resistance, we must learn to use the remaining effective pesticides more efficiently. One of the most effective methods of reducing the development of resistance is to combine their use with other control strategies.

Environmental damage

Concerns over environmental pollution and groundwater contamination make it important to reduce our use of pesticides and their misapplication.

Personal health and safety

Potential exposure of applicators and workers to pesticides and pesticide residues in greenhouses means we must critically evaluate our pesticide use in terms of safety during application and frequency of use.

Monitoring

Careful monitoring provides reliable information to guide your integrated pest management program. The most common greenhouse-monitoring technique is the use of yellow sticky traps (cards or tape) to collect many species of flying insects. These are especially good for whitefly, thrips, leaf miner, fungus gnats, and winged aphids. Note that blue sticky traps have proven especially attractive to western flower thrips. However, if a wide variety of pests is present, yellow traps are a better choice.

When using sticky cards, it is important to provide adequate coverage. Use one card every 100–200 m² and change the traps before too many insects make maintaining a weekly record difficult. In spring and summer, this usually means changing the cards every week when you record the pest numbers.

Another important, and often overlooked, monitoring technique is crop inspection. It is essential for monitoring the presence of plant diseases, mites, wingless aphids, or the immature stages of whitefly and leaf miner. Adopt a regular sampling pattern that provides good coverage of the whole greenhouse, including entry points and areas of concern. Again, weekly records are necessary.

For disease monitoring, inspect foliage weekly and roots (or, for vegetable crops, the bases of the plants) every two weeks. EC and pH should be checked biweekly for each crop grown. Early detection of diseases and sedentary pests (such as aphids or mites) makes control easier and may permit you to contain a problem with only a spot spray.

For successful monitoring, you must do it on a regular basis. The information must be recorded so growers can use it in the future. The type of information that should be recorded includes:

- Date
- Pest identification
- Location in the greenhouse
- Number of insects trapped
- Stage of development (e.g., adults, pupae)
- Diseases present or suspected
- Crop species and cultivar
- Control action (pesticide used, rate, area treated, time taken, etc.)

Cultural Controls

Sanitation

Sanitation is the first step in any pest control program. If a source of infection or infestation is constantly present due to poor hygiene, pest control programs will be expensive and frustrating. Carry out good sanitation practices in the greenhouse and adjoining structures (boiler rooms, etc.), in the immediate vicinity of the greenhouse, and during every stage of crop production.

Proper greenhouse sanitation is a continual, year-round process. ***Cleanliness on its own may not control pest problems, but it is a basic component of any control program.*** It is important to:

- Remove dead and dying leaves and flowers. In roses, removal of and disposal away from the greenhouse of all flowers (including those that will not be sold) can play a significant role in control of thrips.
- Remove crop residues well away and downwind from the greenhouse.
- Preferably burn residues or, alternatively, contain and dispose of them.
- Remove all weeds from inside and immediately outside the greenhouse.
- Keep walks and the surfaces of beds clean.
- Check carefully for pest infestations when bringing new stock into the greenhouse.
- Avoid overwintering garden or house plants in the greenhouse, otherwise pests will be maintained for an early invasion of the next crop.
- Maintain good drainage to eliminate puddles and wet surfaces, as these provide ideal breeding sites for fungus gnats and shoreflies and are a possible source of infection for waterborne diseases.
- If the greenhouse is empty between crops (especially likely with greenhouse vegetables, but also possible in some ornamental greenhouses), heat treatment can be an effective way to remove pest infestations. If temperatures are maintained at >40°C and humidity at <50% for 3–4 days, insect and mite pests will be effectively controlled. This is particularly suitable during the warmer months of the year when these temperatures can be achieved by just closing the vents. ***Note: At higher temperatures, plastic fittings may warp.***
- To prevent disease organisms from carrying over on empty structures, heating pipes, walks, benches, or equipment, spray with one of these options:
    - A 0.5%–1% final solution of sodium hypochlorite bleach. Mix 1 part common household bleach with 9 parts water
    - Floralife D.C.D., a quaternary ammonium compound with fungicidal and bactericidal activity
    - Virkon, a disinfectant with fungicidal, bactericidal, and virucidal activity.

Environmental Control

Environmental factors such as light, temperature, humidity, water, and nutrients can affect not only the plant, but also the pests and diseases that afflict them. The use of environmental controls to manage pests is complex because of the simultaneous effects on crop production. Each case is different and should be looked at carefully. For example, humidity can play an important role in pest and disease development.

- Spider mites prefer hot, dry conditions. Increasing the humidity by the use of overhead misting can help retard the development of this pest.
- During the winter months, thrips are not particularly mobile. This is probably due to low light levels rather than to low temperatures, and it can have implications for monitoring programs. At these times of the year thrips may not be caught by yellow sticky cards, even when thrips are present and actively feeding in the crop.
- Air moisture affects the development of diseases such as powdery mildew and *Botrytis*. This makes these problems susceptible to improvement by environmental controls (see Major Greenhouse Flower Diseases).

Soil Pasteurization Methods

Greenhouse media and field soils contain weed seeds, insects, bacteria, and fungi that may be harmful to the plants being grown. This includes potting mixes and their components, unless guaranteed sterile or pasteurized by the manufacturer. Soil and potting mixes can be pasteurized to eliminate these harmful organisms. Ideally, this is accomplished without injuring beneficial soil organisms.

Steam

Steam is the most common heat source for pasteurization. There are different ways of handling steam, depending on the type of crop being grown.

- When pasteurizing soil for vegetable seedlings or potted plants, growers find it efficient to inject steam into the bottom of a wagon or old truck body.

- After cooling, the pasteurized soil can be moved in masses to the area in which it will be used.

Growers of cut flower or vegetable crops follow two main techniques:
- If ground beds are drained with agricultural tile, it is very simple to inject steam into these tiles and pasteurize the soil on the sides and above them. The top of the tile should be 40 cm below the surface and the rows on 60 cm centres.
- If tiles are not installed, cover the bed with a tarpaulin. Inject steam directly under the tarpaulin through either a canvas hose or a perforated, flexible plastic field tile. This ensures even distribution. Soil should be in fine tilth to allow rapid, uniform penetration of the steam. The soil should be free from clods and undecomposed crop remains.
- When using rock wool, note that steaming time depends on the wetness of the rock wool and the steam temperature. Steaming at 90°C for 30 minutes should be adequate. Generally, the wetter the rock wool, the longer the steaming period. For this reason, the substrate should be as dry as possible before steaming. Rock wool stacked on pallets without the polyethylene bags can be steam-sterilized in two hours. Rock wool wrapped in polyethylene requires five hours of steaming. The rock wool should not be stacked higher than 1.5 m. To stabilize the stacked slabs, place each row at right angles to the previous one. In addition, leave a 2.5 cm (1 in.) space between individual slabs to allow for better steam penetration.

Time-temperature relationships to destroy undesirable organisms

The following chart gives the time/temperature relationships necessary to destroy undesirable organisms. It shows that most organisms of concern to growers can be eliminated under ideal conditions of 60°C for 30 minutes.

Weeds (most)	70°C–80°C for 15 min
Insects and Mites	60°C–71°C for 20 min
Bacteria (most)	60°C for 10 min
Fusarium	57°C for 30 min
Botrytis	55°C for 15 min
Nematodes	55°C for 30 min
Rhizoctonia	52°C for 30 min
Sclerotinia	50°C for 5 min
Pythium	46°C for 40 min

When temperatures rise above 82°C, beneficial soil organisms begin to be destroyed. If the soil is heated to too high a temperature for too long a time, it becomes sterile. It is then subject to a greater degree of infection than previously, as all beneficial organisms have been destroyed. There are many other undesirable effects of over-steaming, such as:

- Excessive ammonia release
- Manganese toxicity
- Higher total salt levels
- Destruction of organic matter

Aerated Steam

Aerated steam is being used more widely today. In this system, steam mixes with air in a chamber. The mixture is used at 70°C to pasteurize soil while avoiding any of the hazards of over-steaming. Unless there are specific problems, a soil temperature of 70°C is adequate for most insect and disease problems.

Electric Soil Pasteurizers

Electric soil pasteurizers are useful where you must pasteurize small volumes of soil and no other method is available. ***Note that these can overcook the soil very easily.*** For the soil temperature between the finned heat sources to reach 82°C, the fins themselves must be at a higher temperature.

Chemical Fumigants

Chemical fumigants such as Basamid, methyl bromide, Telone, Vapam, and Vorlex can be used for pasteurizing soil for potting or in greenhouse beds or benches. Each of these fumigants has a specific rate and activity against soilborne insects, diseases, nematodes, and weeds. ***Note that some formulations may be less effective against certain types of pests— always read the manufacturer's label.*** Be sure to protect crops in adjoining beds or benches from accidental exposure to escaped fumes.

Fumigants listed below are effective as preplanting treatments for greenhouse soil beds. The amounts shown are for use on 100 m^2:

TABLE 3–1. Chemical Fumigants for Soil Treatments

Control of nematodes only	
Telone IIB	2.0 L
Telone C-17	2.0 L
Vorlex Plus	2.5 L
Control of nematodes, fungi, insects, and some bacteria	
Basamid (granular)	3.25–5 kg worked in to a depth of 15-23 cm
Vapam (liquid)	10 L
Vorlex Plus (liquid)	6 L
Methyl bromide/Chloropicrin	Pressurized cans 98%/2%: 7.5–10 kg
	Injectable 68%/31.8%: 2.5–3.65 kg

Notes on Methyl Bromide

Methyl bromide must be applied by licensed applicators only! *The bromide residue that lingers in the soil after using methyl bromide may reduce the germination and/or growth of salvia, dianthus, ageratum, alyssum, antirrhinum, aster, calendula, celosia, chrysanthemum, cleome, coleus, coreopsis, dahlia, digitalis, godetia, helichrysum, iberis, lobelia, matricaria, myosotis, nemesia, nierembergia, portulaca, salpiglossis, verbena, vinca, and viola.*

Do not use methyl bromide prior to planting a lettuce crop or other leafy vegetables.

Weed Control Methods

Control of weeds inside and outside the greenhouse is an important part of any pest management program. Weeds can provide a refuge for insect pests and act as a reservoir for diseases. A 5-m strip of carefully maintained lawn around and between greenhouses will also decrease the danger of invasion by insects and diseases from outside. Fescue grasses have been shown to be one of the least preferred grasses of western flower thrips, information that may be useful for lawn plantings around greenhouses.

Herbicide application, cultivation, and hand weeding are the most practical methods of controlling weeds in and around greenhouses. However, other methods may be useful to reduce the amount of labour required to keep weeds under control.

Steam

As mentioned above, steam used to pasteurize soil will kill weeds and most weed seeds if the soil temperature can be held at 70°–80°C for 15 minutes. Weed seeds in the outer layer of cooler soil and weed seeds with hard seed coats may not be killed.

Soil Fumigation

Metam sodium (Vapam), dazomet (Basamid), and Vorlex are useful in treating seedbeds and potting soil. They break down in the soil to produce a gas that kills many weed seeds, nematodes, and fungi that cause damping-off and other plant diseases.

Methyl bromide is also effective for weed control and general soil sterilizing. It comes as a liquid and forms a poisonous gas when released from the container. Methyl bromide must be used, ***by licensed applicators only,*** *under a gasproof cover, usually plastic.*

Herbicides

OMAFRA Publication 75, Guide to Chemical Weed Control, contains information on herbicides registered for use in Ontario. Treatments listed in the publication are subject to extensive field trials and observation on farms. Herbicides may be particularly useful for weed control outside, but no herbicides are registered for use inside the greenhouse.

There is potential for crop damage if any herbicide is used incorrectly. Always turn fans off so as not to draw herbicides into the greenhouse. A copy of Publication 75 is available at any OMAFRA Resource Centre or from Crop Advisors. The information on chemicals, safety precautions, calibrations, and care and use of sprayers should be followed carefully.

Where unwanted herbicide residues remain in soil, an application of activated charcoal can reduce the problem. The rate varies depending on the type of chemical contaminant and its concentration. A usual range is 0.5–1.5 kg/100 m^2.

Resistant Cultivars

Many plant species display varietal differences in their susceptibility to insect and disease attack. Genetic manipulation of crops can provide growers with cultivars resistant to one or more insects or diseases. For example, greenhouse tomato growers seldom experience problems with Fusarium Crown and Root Rot because resistant varieties have been developed, and powdery mildew-tolerant cucumber varieties are increasingly used. Although ornamental plant breeders have not taken great advantage of host plant resistance, it offers potential for future advancements in pest management.

In the meantime, growers with pest problems can improve their pest management program by looking closely at the varieties grown and at how these varieties are affected by pests. You can use susceptible varieties as indicators for pests and diseases. Spot-spray the susceptible variety when pests or diseases occur — this provides effective control and reduces the amount of pesticide applied. Although market demands determine the varieties grown, it may be possible to eliminate or reduce the amount of a susceptible variety and replace it with a more resistant one.

Physical Control

Screening

Using screens over vents can greatly reduce the entrance of insect pests from outside. In warmer climates where pests occur outside all year, screening has become an established part of IPM programs. While not as common in temperate areas, screening is becoming more accepted and its value more apparent.

Screening removes an important variable from a grower's pest management program—the movement of pests into the greenhouse from outside. This includes common greenhouse pests such as thrips, aphids, and whiteflies, but also some less common pests such as tarnished plant bugs and European corn borers, which can become major pest problems when pesticide use is reduced (e.g., in biological control programs). Benefits of using insect screening have been demonstrated in Israel and California. In Ontario, growers who have installed screens have reported that pest levels and pesticide use are reduced, and effectiveness of pest control (especially biological control) measures improved.

The most important consideration for a grower wishing to screen a greenhouse is to determine which pests need to be excluded. The size of the pest determines the mesh size of the screen that is needed for that purpose. Large mesh sizes of the type normally found in household screens are inadequate for excluding most major greenhouse pests, however, they can be useful in keeping out occasional larger pests such as tarnished plant bugs and lepidopteran (moth) pests. For smaller insects such as thrips, screens must be of a very fine mesh for total exclusion. When you have multiple pests of concern, the mesh size you choose should exclude the smallest of these pests. Note, though, that even larger mesh sizes can significantly reduce air movement into the greenhouse. Increased intake vent surface area is needed to compensate for the decreased airflow. Forced ventilation/wall vents are much easier and less expensive to screen than top vents.

A major concern of growers who are considering screening is the reduction in air flow. Reduced air flow can lead to overheating of the greenhouse, and stress on the fans (in the case of fan-ventilated greenhouses), which have to work harder to pull the same amount of air through the partially blocked vent. Reduced ventilation is a valid concern, but it can be addressed by increasing the surface area of the vent. In many situations this has been done by building a screened framework around the vent opening, a tactic that has worked very successfully where growers have used it. The goal is to ensure that the final surface area of the vents provides sufficient air exchange to allow adequate cooling of the greenhouse. There are several methods available for determining the increase in surface area of the vents required for any given greenhouse, but factors such as screen mesh size, fan capacity, and static pressure drop (the difference in air pressure between inside and outside the greenhouse when the fans are running) are important. Although there are software programs available to assist with these calculations, they can be complicated and are generally best left to the screening manufacturers.

The small pore size means that the screens are very prone to blockage with dust and other deposits, especially in the summer. Such blockage will reduce air flow through the screens and may contribute to excessively high temperature conditions. It is therefore important that the screens be regularly cleaned. It is also important to incorporate easy access in the design of the screens to facilitate its cleaning. Screens should be washed from the inside with a high pressure hose. ***It is very important that this not be done when the fans are operating, because the water will block the pore openings and completely stop air flow, leading to overheating of the greenhouse.***

The effectiveness of the screens depends on their ability to exclude flying insects. Entry points will be created by any tears or holes, which should be repaired as soon as possible. Small tears can be simply repaired by gluing a piece of screening over the hole.

The cost of screening will depend on several factors: the final screening design; the increase in surface area needed to maintain adequate ventilation; the cost of the screening material; whether roof vents or side vents are to be screened; the frequency of replacement; frequency of cleaning, etc. The biggest variable is the difference in cost between installing screens in a force-ventilated, side-vented greenhouse, and a passively vented greenhouse with roof vents. Nevertheless, reports from growers who have installed screens over side vents in force-ventilated greenhouses suggest a rapid payback from reduced pesticide costs and improved pest management.

For more information, see OMAFRA Factsheet 290/626, *Screening of Greenhouses for Insect Exclusion.*

Other Physical Controls

Yellow sticky tape is another physical control that can provide useful additional control of flying insect pests. It works on the same principle as the sticky cards used for monitoring. String tape along beds or benches, or hang it vertically within the crop, to provide significant supplementary control in conjunction with other control methods.

Biological Control

Biological control is the use of living organisms such as insects, mites, nematodes, fungi, and bacteria to control pests such as insects, mites, and diseases. Biological control requires very different approaches for vegetables and for floriculture. While widespread in greenhouse vegetable crops, biological control has been used only recently in flower crops.

Biological control involves more than just the release of parasites or predators. To be successful it is important to plan at least several months in advance. The following steps should be addressed when considering the use of biological control:

1. Develop a list of resources that you can use to help with your program (this may include producers/suppppliers of biocontrol agents, other growers, extension specialists, researchers, consultants). Attend courses, seminars, workshops, read magazines and newsletters, use the Internet to find out as much as you can about biocontrol. Determine which pests you want to control and which are the most appropriate natural enemies to use.
2. Start in a small and isolated part of the greenhouse if possible. This allows you to focus more closely on the area being used and to become more comfortable with the use of biological control without worrying that the entire crop is dependent on your first use of biocontrol being successful. In subsequent years, the use of natural enemies can be expanded to include other areas of the operation.
3. If possible, screen the area to be used. Movement into the greenhouse of pests from outside is unpredictable from year to year but can swamp a biocontrol program and make it difficult for the natural enemies to maintain control. With screening, you have to worry only about the pests inside the greenhouse. (See *Screening*).
4. Ensure that all your staff are aware of what you are doing and why. They are in the greenhouse every day performing the routine crop management tasks and if trained can recognize problems at a very early stage.
5. Many registered pesticides can have long-term (2–3 months) residual impact against natural enemies. Check through your pesticide spray records over the previous several months. If such pesticides have been used, then you need to wait the appropriate length of time before starting. You may need to use products with less residual impact to control pests and diseases during this period. Effects of many pesticides are listed in tables below or are available from biocontrol suppliers.
6. Learn how to check incoming biocontrol agents to determine if they are alive and well. Work with your supplier. The quality of natural enemies produced by the major insectaries is excellent, but occasionally problems can arise in shipping. Your supplier needs to know about any problems in quality so that the causes can be identified and corrected.
7. Follow instructions in storing and releasing the natural enemies. Many of them can be stored for only a short period of time under fairly specific conditions.
8. Monitor the populations of natural enemies and the progress of the biocontrol program. It is as important as monitoring the pest populations. Make use of:
    - Make use of sticky cards to monitor flying insects, especially the parasitic wasps. Be aware however, that some (e.g., Eretmocerus) are highly attracted to yellow, and too many sticky cards may be detrimental to the program.

  - The impact of the natural enemy on the pest; e.g., parasitism of whitefly by Encarsia and aphids by Aphidius parasitic wasps is easily checked.
  - Visual inspection of the crop for natural enemies such as predatory mites, which don't fly. Inspect the crop especially in areas of highest pest numbers.
  - Regular monitoring of pests to determine if populations are decreasing.

9. Make use of compatible pesticides if necessary. Such pesticides should be identified prior to starting a program so that you are ready to use them if necessary. See tables below or refer to lists available from suppliers.
10. Be patient. It takes some experience to understand a system of biocontrol if you are using it for the first time. Make use of others who have experience if you are concerned with the way the program is progressing.

Commercially produced biocontrol agents are available for all the major greenhouse insect and mite pests, but not yet for diseases. For more details about the implementation of biological control or about supplies of parasites/predators, consult your Greenhouse Pest Management Advisor or Horticultural Crop Advisor.

TABLE 3–2. Biocontrol Agents for Principal Greenhouse Pests

Pest	Biocontrol Agent
Whitefly (*Trialeurodes vaporariorum or Bemisia argentifolii*)	*Encarsia formosa* (parasite)[1] *Eretmocerus eremicus* (parasite)[1] *Delphastus pusillus* (predator)[2] *Dicyphus hesperus* (predator)[2]
Spider Mite (*Tetranychus urticae*)	*Phytoseiulus persimilis* (predator)[2] *Feltiella acarisuga* (predator)[2]
Western Flower Thrips (*Frankliniella occidentalis*)	*Amblyseius* spp. (predator)[2] *Orius* spp. (predator)[2] *Hypoaspis* sp. (predator)[2]
Aphids: Various species, especially green peach aphid (*Myzus persicae*) or melon aphid (*Aphis gossypii*)	*Aphidius* spp. (parasite)[1] *Aphidoletes aphidimyza* (predator)[2] Ladybeetles (*Harmonia* and *Hippodamia)* Lacewings (predators)[2]
Fungus Gnat (*Bradysia* and *Corynoptera* spp.)	*Hypoaspis* (predator)[2] Nematodes—*Steinernema* sp.
Leaf Miner (*Liriomyza trifolii*)	*Diglyphus* sp. (parasite)[1] *Dacnusa* sp. (parasite)[1]

[1] Parasite: usually requires only one host for completion of development, often killing it by living on or in its body.

[2] Predator: feeds on its prey (pest) by catching them, but otherwise lives independently of them. It must consume more than one indivivual to reach maturity.

Caution is required when using pesticides along with biocontrols, since most pesticides are harmful to natural enemies. Application of just one harmful pesticide can prevent any further use of biocontrol agents for an extended period of time.

TABLE 3–3. Reported Effects of Registered Fungicides on Biological Control Agents[1] [2] [3]

Fungicides	*Encarsia formosa* and *Aphidius*	*Phytoseiulus persimilis*	*Amblyseius cucumeris* and *Hypoaspis*	*Aphidoletes aphidimyza*	*Orius* spp.
Aliette	–	S	S	I	–
Botran	S	S	S	S	S
Captan/Maestro	S	S	S	S	S
Daconil	S	S	I	S	S
Decree	–	–	–	–	–
Easout	S	H (14–21)	H (14–21)	S	S
Meltatox	S	S	–	–	–
Mycostop	S	S	S	S	S
Nova	S	S	S	–	S
Phyton 27	S	S	S	S	S
Quintozene	–	–	–	–	–
Rovral	S	S	S	S	S
Subdue	I	I	I	S	
Truban	S	S	S	S	–

[1] Numbers in parentheses refer to residual toxicity to biological agent, in days. S = Safe; H = Harmful; I = Intermediate; "—" means no data is available, *so presume toxic unless otherwise proven.*

[2] This table serves only as a guide to possible effects of pesticides. *Variations in toxicity may occur under varying conditions.*

[3] This table was compiled from information produced by *Applied Bionomics Ltd.* and *Koppert Biological Systems.* Where discrepancies existed in the available information, it provides a range of residual toxicities *or* the more conservative figure.

TABLE 3–4. Reported Effects of Registered Pesticides on Biological Control Agents[1] [2] [3]

Insecticides	*Encarsia formosa* and *Aphidius*	*Phytoseiulus persimilis*	*Amblyseius cucumeris* and *Hypoaspis*	*Aphidoletes aphidimyza*	*Orius* spp.
Ambush	H(56–84)	H(56–84)	H(56–84)	H(56–84)	H(56–84)
Citation	S	S	S	S	S
DDVP/Sanex Vapo	H(7)	H(3)	H(3)	H(3)	H(7)
Decis	H(56–84)	H(56–84)	H(56–84)	H(56–84)	H(56–84)
Diazinon	H(28–42)	H(7)	H(7–21)	H(42–56)	H(30)
Dibrom	H(7)	H(3)	H(3)	H(7)	H(3)
Dimilin	S	S	S	S	H
Dipel	H(3)	S	S	I	S
Dyno-Mite	H (3–4)	I	H (0)	–	–
Enstar II	I	S	S	–	–
Impower	S	S	S	S	H (28–42)
Ins. Soap	H(0)	H(0)	H(0)	H(0)	H(0)
Kelthane	H(14)	H(14)	H(30)	H(4)	I
Malathion	H(56–84)	H(7–14)	H(56–84)	H(70)	H
Metasystox–R	H(56–84)	H(7)	H	H	H
Nicotine (F)	I(3)	I	H(1)	H(1)	I
Oil (Refined mineral)	H(0)	H(0)	H(0)	H(0)	H
Orthene	H(56–84)	H(21–28)	H(56–84)	H(56–84)	H
Parathion	H(56–84)	H(14)	H(42–56)	H(56–84)	H
Pentac	H(42–56)	H(14)	H(14–28)	S	—
Pirliss (Pirimor)	I(3–4)	I(3–4)	I(3–4)	H(7)	S
Sulfotep	H(56–84)	H(70)	H(42–56)	H(56–84)	H
Thiodan	H(56–84)	H(4–14)	H(42–70)	H(56–84)	H
Trumpet	H(21)	H(21)	H(21)	H(21)	H
Vectobac	S	S	S	S	S
Vendex	S	S	S	S	S

[1] Numbers in parentheses refer to residual toxicity to biological agent, in days. S = Safe; H = Harmful; I = Intermediate; "—" means no data is available, *so presume toxic unless otherwise proven.*

[2] This table serves only as a guide to possible effects of pesticides. *Variations in toxicity may occur under varying conditions.*

[3] This table was compiled from information produced by *Applied Bionomics Ltd.* and *Koppert Biological Systems.* Where discrepancies existed in the available information, it provides a range of residual toxicities *or* the more conservative figure.

Chemical Control

While pesticides will remain an important component of our greenhouse pest management programs, we must carefully monitor their use. For the reasons noted above, we must make the best possible use of those that are available. There are several important considerations:

Resistance

Resistance can develop to any pesticide used incorrectly or too often. Although there are benefits from new product registrations, growers should not simply wait for the latest advance in pesticide chemistry. The long-term problems presented by pesticide resistance far outweigh the short-term gains of a new product if it is used incorrectly.

Resistance is the evolutionary adaptation of a population to survive a pesticide dose that is lethal to most of its individuals. It is an inherited trait, which is passed onto future generations. While resistance does not develop within an individual during its lifetime, it usually exists in a population at very low frequencies (too low to be measured or noticeable). The frequency of resistance increases when pesticide exposure kills susceptible individuals while allowing successively greater numbers of resistant individuals to survive.

Resistance management programs aim to reduce the pressure applied to pest populations by pesticides. We use diverse control methods to reduce the need for pesticides. There are several ways to do this, mirroring the approach of IPM programs. Growers using IPM programs, good monitoring techniques, and cultural, biological, and physical controls, are practising resistance management at the same time.

Note that when pesticides are used in an IPM program, the rate at which resistance develops increases if one class of pesticides (e.g., organophosphorus, synthetic pyrethoid, carbamate) is used for a prolonged period. To slow the rate of resistance development, rotate pesticide classes every few weeks or for a period equal to the generation time of the pest being controlled (see *Insecticide and Fungicide Toxicity* for pesticide classes).

Everyone in the industry must use pesticides responsibly so that new products do not lose their effectiveness within a year or two of registration.

Pesticide Application

The most common cause of control failure is *not* resistance. Several other factors determine the effectiveness of a particular pesticide application:

- Make sure that pesticide rates are calculated and measured accurately.
- Good coverage is needed for good pest control. Simple changes such as walking more slowly through the crop, or walking every aisle instead of every other one, significantly improve performance.
- Spray equipment must be maintained in good condition, with spray nozzles changed on a regular basis. Older nozzles become worn, which can alter spray pattern and droplet size.
- Consider the use of different application technologies. High-volume, low-volume, and electrostatic-spray application all have their place in the greenhouse for appropriate purposes.
- Perhaps the biggest improvement comes from timing and targeting sprays more effectively. To do this, you must implement an IPM program that provides the information required to decide when, where, and why a pesticide application is needed. Sprays can then be applied where most needed (e.g., as spot sprays), when they will provide optimal control, and directly at the appropriate pest at the correct life stage.
- Pesticide effectiveness will vary (often considerably) from greenhouse to greenhouse, depending on factors such as the usage history of a particular product, the method of application, the time of application, and the water quality. Water pH should be adjusted to 5.5–6.0; at pH>7, the pesticide may degrade rapidly.

Soil Drenches

Although soil drenches should not replace a thorough greenhouse pasteurization program, they are useful for preventing recontamination or eliminating pathogens in the soil or the basal parts of the plant. A root inspection-monitoring program should be the first line of defence against root diseases and soil-dwelling insects such as fungus gnats.

Some drenches are taken up from the soil by plant roots. In this case, the drenches are systemic, and the whole plant is effectively treated against pests. Generally, apply 12 L of drench per m^2 of bench area or 150–180 mL of drench per 15-cm pot. Follow the manufacturer's directions carefully.

Pesticide Compatibility

- Pesticides recommended in this publication are for individual application to a crop.
- Before mixing pesticides, read the product labels carefully for compatibility statements or contact the supplier.
- Avoid mixing EC formulations.
- Herbicides should never be mixed with fungicides and insecticides; apply with spray equipment reserved for herbicide use only.

Pesticide Injury To Flower Crops

Although greenhouse insecticides have been selected and formulated to avoid plant injury, damage can still occur under some conditions. Consider these general rules before applying pesticides:

- No insecticide is safe on all plants under all conditions, although wettable powders are generally less injurious than liquid formulations.
- A material may be safe when applied to dry foliage but can cause injury when used on wet foliage e.g., smokes.
- Weather conditions at the time of application are important. Pesticides are more likely to be phytotoxic when applied during bright sunny weather than if applied during dull overcast conditions.
- Well-watered, unstressed plants are less likely to be damaged by pesticides.
- Low-volume applications are generally less likely to cause plant injury than high-volume applications.

Pesticide Hazards

The following list of possible hazards was compiled from grower experiences and pesticide label warnings.

This list is not comprehensive! When using a product for the first time on a new crop, always test it first on several different varieties and on a small area.

- ***Avid*** may damage Shasta daisy and fern.
- ***Daconil 2787*** may damage open blooms on some plants (e.g., exacum).
- ***D.C.D.*** has been reported to cause damage to some greenhouse vegetable crops.
- ***DDVP (Vapona, dichlorvos)*** is injurious on some older chrysanthemum varieties (e.g., Shasta and Pink Champagne). It also damages some varieties of snapdragon, tradescantia, some crassula, fern and some rose varieties. Crop should be dry when applied. DDVP smoke will damage open blooms of regal geranium.
- ***Diazinon*** is not for use on gardenia, poinsettia, hibiscus, stephanotis, pilea, hydrangea, or cyclamen foliage.
- ***Dibrom*** injures some ornamentals, including some chrysanthemum varieties, and can cause flower damage to cucumber.
- ***Dyno-Mite*** may cause colour change in blossoms of petunia (cv. White madness).
- ***Malathion*** should not be used on fern, petunia, crassula, orchid, sweet pea, cucurbits, African violet, gloxinia, rieger begonia, and some carnation and rose varieties.
- ***Manzate 200*** may cause stunting when used in repeated soil drenches on cyclamen, exacum, and poinsettia, particularly when soil is dry.
- ***Metasystox-R*** damages lilies, rieger begonia, geraniums, and some older chrysanthemum varieties (e.g., Hurricane, Iceberg, Whitetop, and Pennant).
- ***Nicotine*** may injure lilies and some chrysanthemum varieties. Do not smoke on open blooms of snapdragon, impatiens, geraniums, or African violets. It may injure wet leaves of tomato and cucumber
- ***Orthene*** is injurious to African violet, poinsettia, gloxinia, and many varieties of geranium.
- ***Pentac Aquaflow*** causes some foliage damage on chrysanthemums. Do not apply to open blooms, especially hydrangea.
- ***Pirimor/Pirliss*** should not be applied to Icecap, Goldcap, and related varieties of chrysanthemum.
- ***Safers Insecticidal Soap*** should not be used on poinsettia, maidenhair fern, sweet pea, or nasturtium.
- ***Sevin (carbaryl)*** should not be used on Boston ivy or Virginia creeper.
- ***Thiodan (endosulfan)*** may injure some geranium varieties. Emulsifiable concentrate has injured Bonnaffon Deluxe and some older chrysanthemum varieties. There have been reports of injury to cineraria, gardenia, gloxinia, poinsettia, rose, African violet, and pothos. If plants are well watered and not stressed, there is less likelihood of damage.
- ***Trumpet*** may burn cineraria.

4. Major Insect and Mite Pests Affecting Flowers

Thrips

Description and Life History

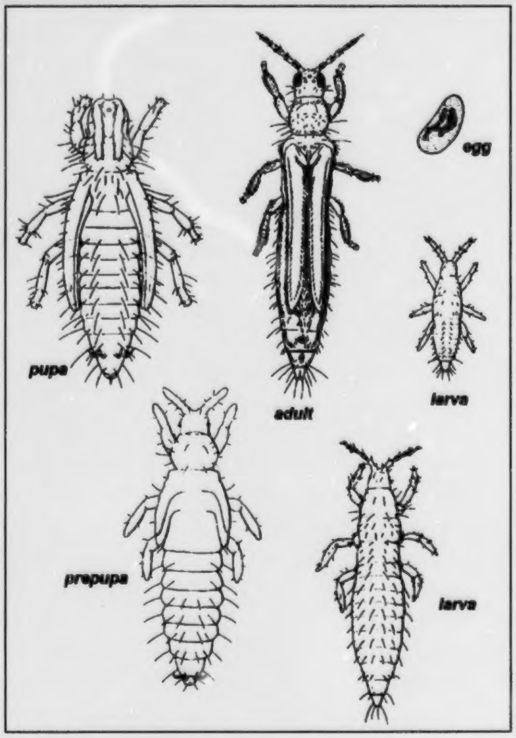
Thrips are tiny, slender, agile insects about 1.5–2 mm in length when fully developed. Adults vary in colour from dark brown or black through to yellow or straw-brown. Immatures are usually white or yellow with red eyes. Several thrips species are found in the greenhouse, including eastern flower thrips, onion thrips, and western flower thrips (WFT).

All thrips have a similar life cycle. The adult female lays tiny white eggs inside the leaf tissue. The eggs hatch in 5–7 days, and the white larvae emerge to feed on the leaves and petals. They pass through two larval stages, a prepupal stage and a pupal stage (on the soil or plant) before becoming adults. Adults can live up to 7 weeks. A new generation may occur every 20–35 days, depending on the temperature.

Damage

- Piercing/sucking mouthparts cause white streaked areas on leaves or translucent spots on flower petals. Feeding is characterized by tiny, black, fecal deposits on leaf surfaces. Adult females can also damage fruit quality (e.g., of tomatoes) by laying eggs in the fruit. Small whitish "ghost-spots" appear where eggs are laid, which cause uneven fruit ripening.
- Thrips also rapidly develop pesticide resistance. They can carry impatiens necrotic spot virus/ tomato spotted wilt virus (INSV/TSWV), which can devastate many common greenhouse crops. Proper diagnosis is essential, as these viruses have a wide host range and produce a wide variety of symptoms. Control of INSV/TSWV is difficult, involving thrips population management, removal of infected plants, and good weed control inside and outside the greenhouse. Use of indicator plants such as petunia or fava bean can be a useful means for early detection of INSV/TSWV.

FIGURE 4–1. Western Flower Thrip



Control Strategies

- Control should employ a good monitoring program using yellow or blue (both very attractive colours to WFT) sticky cards and regular crop inspection.
- All stages of the thrips (except eggs) can be detected by tapping buds or flowers over a sheet of white paper.

Biological Control

- Four biological control agents are available for thrips control: the predatory mites *Amblyseius cucumeris, Amblyseius degenerans,* and *Hypoaspis,* and the predatory bug *Orius insidiosus.*
- You will probably gain the best control by using more than one in combination. Introduce them

when pest levels are low, using a sufficient quantity to achieve success.

Amblyseius cucumeris

This buff-coloured predator feeds mainly on the first nymphal stage of thrips.

- *Amblyseius cucumeris* is usually shipped to growers in a mixture that includes bran and bran mites. The bran provides food for the bran mites, which are themselves food for the predatory mites. The bran/mite mixture is available in small sachets or in containers from which the mixture is sprinkled directly onto the crop. The sachets serve as small rearing units from which predatory mites emerge over several weeks.
- Always examine the bran mixture prior to use. The bran should not be mouldy or smell of ammonia, and live predatory and bran mites should be visible.
- Healthy predatory mites move rapidly, whereas bran mites move more slowly. Hang sachets in sheltered positions to minimize dehydration of the bag contents. Rates of application of this predator vary with crop and level of thrips infestation. Contact your OMAFRA IPM Specialist or biological control supplier for suggested rates.

Amblyseius degenerans

This predator differs from *A. cucumeris* in appearance and in being able to tolerate less humid conditions.

- It is dark, very agile, and reproduces very well on pollen.
- It can be reared on castor bean plants, which you may use as release points for the predator within the greenhouse.
- It performs best in situations where it has a pollen source to encourage establishment (e.g., greenhouse peppers). Because of this, it is unlikely to be the best option for most floricultural crops.

Hypoaspis

This soil-dwelling mite provides additional thrips control by feeding on pupae in the crop media. For more details, see *Fungus Gnats*.

Orius insidiosus

Orius insidiosus, the minute pirate bug, is a winged predator that consumes all mobile stages of thrips. Adults are black with white and cream markings on the wings. The youngest nymphs are yellow, while the oldest ones are a dark mahogany brown.

- *Orius* also feeds on pollen, spider mites, aphids, whiteflies, moth eggs, and young caterpillars. However, its preferred food source is thrips.
- Pirate bugs are sensitive to day length. Do not release them in greenhouses before mid-March unless you can provide at least 13 hours of light.

Chemical Control

Chemical control of WFT can be difficult. They tolerate most pesticides and feed deep within the flower head or on developing leaves. This makes them a difficult target for insecticides, so thorough coverage is essential. General recommendations regarding pesticide use for thrips control are as follows:

- At the action threshold (when thrips population levels dictate spraying to prevent economically damaging numbers from appearing), spray 4–5 days apart for three consecutive applications.
- Rotate chemical classes and use a single chemical class only for the duration of the thrips' life cycle. This generally means using a different class every 2–3 weeks depending on time of year. Generation times are longer at cooler temperatures.
- Apply pesticides in early morning and late afternoon, when flight activity of thrips is at a peak. This increases exposure of the thrips to the pesticides.

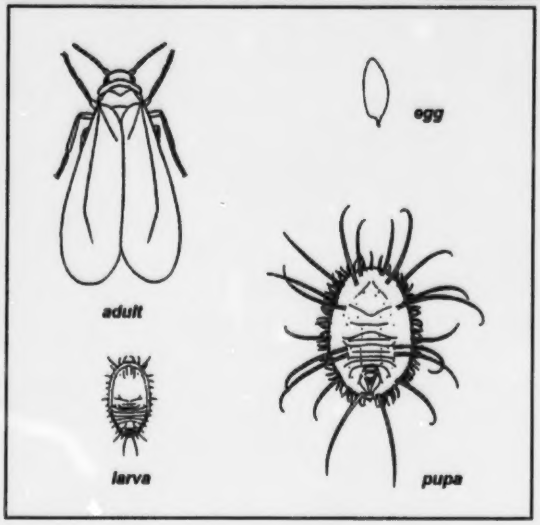
Whiteflies

Description and Life History

Adult whiteflies are small, winged, white insects about 1.5–2 mm long. They lay eggs on the underside of the youngest leaves and are too small to be seen clearly without a microscope. A female whitefly may lay up to 300 eggs during her lifetime and can live up to two months. The nymphs or crawlers hatch in 5–10 days, are flat and scale-like, and crawl around for a short while before becoming immobile.

Adults emerge after three nymphal stages and one pupal stage. Old pupal skins and adults may be found on the underside of lower leaves, which may have symptoms of wilt. On average, the whitefly completes its life cycle in 35 days at 18°C and in 18 days at 30°C. Whiteflies have no special overwintering stage and can usually survive as long as some kind of plant life is around.

FIGURE 4–2. Greenhouse Whitefly



Species of Whiteflies

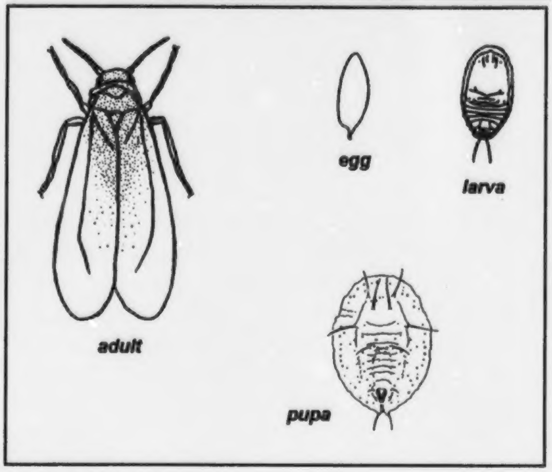
Two whiteflies concern growers in Ontario: the greenhouse whitefly (GWF) and the silverleaf whitefly (SLWF). The GWF and SLWF adults look very similar, albeit with some differences:

- The SLWF is slightly smaller than GWF, and its body is more yellow.
- At rest, SLWF holds its wings tent-like above its body, while the GWF holds them flatter and more parallel to the surface on which it is resting.
- The major diagnostic differences between GWF and SLWF appear in the pupal stages. The GWF pupa is raised off the leaf surface and is surrounded by a fringe of hairs, while the SLWF pupa sits flat on the leaf and does not have a fringe. These features are best seen with a microscope.
- SLWF fly in a more direct manner, while the GWF assume a more haphazard flight pattern.
- The life cycle of SLWF takes longer to complete.
- SLWF is less adapted to cold conditions.

Damage

- Piercing/sucking mouthparts allow whiteflies to remove sap from the plant, reducing plant vigour.
- Whiteflies excrete large amounts of a sugary substance called honeydew. Honeydew promotes the growth of a black sooty mould fungus on leaf and fruit surfaces, reducing photosynthesis and fruit quality respectively. The sooty mould itself does not damage the plants.
- Whiteflies can transmit viruses. For example, the SLWF is reported to transmit over 60 viruses, and the GWF has been associated with the spread of beet pseudo-yellows virus in cucumbers.

FIGURE 4–3. Silverleaf Whitefly



Control Strategies

- Implement a routine monitoring program using yellow sticky cards and plant inspections.
- Use host plants more attractive to whiteflies than the main crop as an early detection tool or as a trap plant. Plant species such as eggplant and fuchsia can be used for these purposes.
- Identify the whitefly species present on the crop.
- React promptly when you observe whitefly adults either on cards or on terminal leaves.
- Maintain good weed control inside and outside the greenhouse.

Biological Control

- Two parasitic wasps are commercially available for whitefly control: *Encarsia formosa* and *Eretmocerus eremicus. Encarsia formosa* is more effective against GWF but provides some control against SLWF. *Eretmocerus* is more effective against SLWF but also provides good control of GWF. A small, black beetle, *Delphastus pusillus* is also available commercially but is likely to be effective only where there are heavy populations of whitefly (a situation that most growers would want to control more quickly with pesticides).
- Good sanitation, weed control, and low whitefly numbers to begin with are essential for successful biological control of whitefly.

Encarsia formosa

About 0.6 mm long, adult wasps are parasites that kill whiteflies mainly by laying eggs into the immature stages or scales (mostly the third and fourth larval stages). Adult *Encarsia* can live for a few days to a month depending on the temperature. Females lay 50–350 eggs in their lifetime. A greenhouse whitefly scale turns black in 10–14 days after being parasitized. On average, the adult wasp emerges two weeks later. When the adult develops fully, it cuts an opening in the top portion of the black scale before emerging. Parasitized SLWF turn tan-brown and are less easily noticed. For biological control of SLWF, consider higher introduction rates.

To use *Encarsia* successfully:

- Avoid pesticides with long residual effects for at least three months before the initial release.
- Monitor the crop for whitefly presence at all production stages and follow population level trends. This permits you to place and time parasite releases more accurately.
- Introduce *Encarsia* at the first sign of whitefly, or preventively before whiteflies are detected. If whiteflies are present before you release *Encarsia*, knock back populations with a low-residual pesticide.
- Don't use *Encarsia* between December and February without adjusting light and temperature conditions to suit the parasite.
- Distribute *Encarsia* in shaded parts of the plant where the parasites are protected from direct sunlight.
- Distribute cards relatively evenly, but place more in areas where whiteflies have been observed. You can achieve more distribution points by purchasing cards with fewer parasitized scales per card.
- Don't remove leaves with immature parasitized scales during deleafing or pruning operations in vegetable crops such as tomato. Such removal slows buildup of *Encarsia* numbers and parasitism rate.
- Continue introducing *Encarsia* until at least about 80% of the scales on older leaves are black. During warmer months when whiteflies migrate into the greenhouses, you may need to maintain or increase introductions.

Eretmocerus eremicus

Adults are about 0.6 mm long and yellow. They lay eggs under the whitefly larvae (preferably 2nd or 3rd stage). This wasp has a sex ratio of 1:1 (male:female). Introduction rates refer to the number of females introduced. This is different from Encarsia, where all individuals are female. Like Encarsia, mortality of whiteflies can be caused by parasitism and by host feeding. The parasitized whitefly pupa is a yellowish-brownish colour (for both GWF and SLWF).

Delphastus pusillus

Delphastus is a predatory beetle. Both adult and larval *Delphastus* feed on whiteflies, particularly on the eggs and nymphs. *Delphastus* are reported to avoid parasitized scales, feeding on principally the non-parasitized scales. This behaviour makes *Delphastus* compatible with *Encarsia*. Use these beetles to supplement the activity of *Encarsia* in reducing whitefly populations. Adult *Delphastus* live for 6–9 weeks. They are reported to require a minimum diet of 10 whitefly eggs/day to reproduce.

Physical Control

Sticky Traps

Use yellow sticky traps in various forms to trap large numbers of adult whiteflies. Large, yellow sticky boards or 30-cm-long yellow sticky tapes can be placed in "hot spots" at a rate of about 1/plant. Alternatively, hang yellow, sticky tape between posts along plant rows. Such tapes will also trap fungus gnats, shoreflies, *Aphidius* spp., and *Encarsia*, especially under low whitefly populations. Be careful in using large quantities of sticky tape in conjunction with parasitoids, especially *Eretmocerus*, which is highly attracted to the colour yellow.

Vacuuming

Hand vacuuming of adults in "hot-spots" is a very effective way to rapidly remove adult whiteflies.

Insect barriers

Installing fine screens over vents and doorways will significantly reduce migration of outdoor populations into greenhouses. Where whiteflies move in from adjacent field crops (e.g., field tomatoes) in large numbers at certain times of the year (e.g., during harvest), screening should be considered as a first line of defence.

Chemical Control

- Whiteflies have developed resistance to many pesticides. Judicious use will extend the effective life of pesticides while delaying the buildup of resistance.
- Rational and judicious pesticide use requires a regular monitoring program, using action thresholds, rotating chemical classes, and incorporating the use of all available non-chemical control strategies.

- When using a systemic insecticide such as Impower, ensure that it is applied correctly. The root system should be well developed and the plant actively growing. If the plant is to be pinched, the product should be applied 10–14 days afterwards. Limit watering for a week after application to reduce the amount of leachate; Impower is very water-soluble and will be easily leached from the pot.

Two-Spotted Spider Mite

Description and Life History

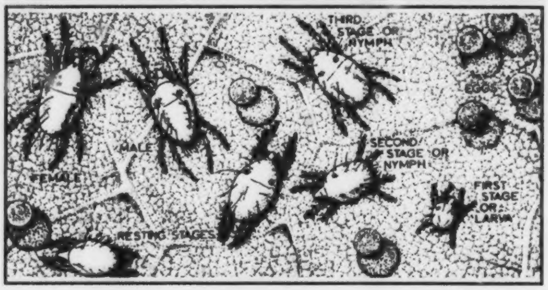
The two-spotted spider mite (TSSM) attacks many greenhouse crops. The eight-legged female adult is approximately 0.5 mm long with a rounded abdomen. The male is distinguished from the female by its smaller, narrower body and pointed abdomen. Adults range from pale yellow to orange to brown. The overwintering or diapausing stage is reddish orange. Day lengths of 12 hours and less, decreasing temperatures, and a deteriorating food source will induce diapause in spider mites. During diapause, spider mites can tolerate very low temperatures. A short spell of heating is not sufficient to break its diapause.

Close examination of leaf undersurfaces will show the mites to be very tiny moving dots. The two dark spots on the body of TSSM are the gut contents showing through the transparent body. After mating, each female mite lays about six pearly white eggs/day. Over an average lifetime, a female lays 100 or more eggs on the undersurface of foliage. Newly hatched mites pass through the typical six-legged larval stage and eight-legged protonymph and deutonymph stages. The last of these is an immobile resting stage, very tolerant of miticides. The life cycle from egg–adult ranges from 23 days at 15°C to just 4 days at 32° C. Development is fastest under hot, dry conditions.

Damage

- All active stages of the two-spotted spider mite feed by piercing the lower epidermis of the leaf with sucking mouthparts.
- The feeding injury starts as a yellow "stippling." As mite numbers increase, the entire leaf appears stippled or light-coloured on the upper surface. Very heavily infested leaves become yellow and brittle, with obvious webbing on the leaves.
- If infestations proceed without control measures, plants may be killed. Mite populations seem to explode at certain times of the year, since the life cycle varies considerably with temperature.
- Other factors, such as humidity, plant nutrition, and cultivar, are important and, at times, can be used to help reduce mite outbreaks.

FIGURE 4–4. Two-Spotted Spider Mite



Control Strategies

- In ornamental crops, monitor with regular crop inspections to detect early infestations *before* mites build up. Pay particular attention to susceptible varieties and crops. In crops such as roses, inspect both upper and lower canopies.
- For vegetable crops, conduct a proper cleanup in August to reduce initial infestations in crops the following spring. Do this just before the overwintering or diapausing phase of the spider mites, since the diapausing mites hibernate in the ground, hollow stems, pipefittings, cracks, and crevices during the fall and winter months. The mites become active again during late winter and early spring. The red mite stages are generally pesticide-resistant and are not as readily fed upon by predators. When the red ex-diapausing mites are detected, use soap sprays on lightly infested leaves and remove and destroy more heavily infested leaves.

Biological Control

- Control spider mites biologically using the predatory mite *Phytoseiulus persimilis.*
- Other predatory mites can be used against this pest, including some strains that are high-temperature tolerant or pesticide resistant. For example, the predatory mite *Amblyseius californicus* is reported to better tolerate dry conditions.

Phytoseiulus persimilis

Phytoseiulus persimilis is about the same size as TSSM but is pear-shaped, pale salmon to bright orange, does not have the two spots, and moves more rapidly on long legs. It feeds specifically on spider mites and does not hibernate.

Without spider mites, the predators die. This means new spider mite infestations require new introductions of the predator. Adult predators feed on about seven adults or 15–20 eggs per day. At 20°C, *persimilis* almost doubles the reproductive rate of the predator. Control with *P. persimilis* is best between 20°C and 26°C. Above 30°C and at humidities under 60%, predators do not thrive and seek cooler, more protected areas lower down in the crop canopy. In contrast, TSSM thrive under these conditions.

- Predators are available commercially either mixed with vermiculite or on bean leaves. With either carrier, treat infested plants at first sign of damage.
- Try to place a few predators onto every infested leaf.
- Before releasing the predators, always ensure that they are alive and very active.

Physical Control

Misting plants and maintaining relatively high humidities help suppress spider mite populations. For example, at 20°C and 36% RH, female TSSMs will lay about seven eggs per day; at 95% humidity, about 30% fewer eggs are laid.

Chemical Control

Because of their great reproductive potential, two-spotted spider mites easily develop pesticide resistance. To effectively manage this pest using pesticides, observe these guidelines:

- Direct sprays to the underside of leaves where spider mites usually congregate.
- The webs in areas of high mite density can protect the mites and the eggs within and beneath the web. In such cases, use higher spray pressures to penetrate the web.
- Because of TSSM's high reproductive potential, use non-chemical control options as much as possible to minimize the development of pesticide resistance.

Aphids

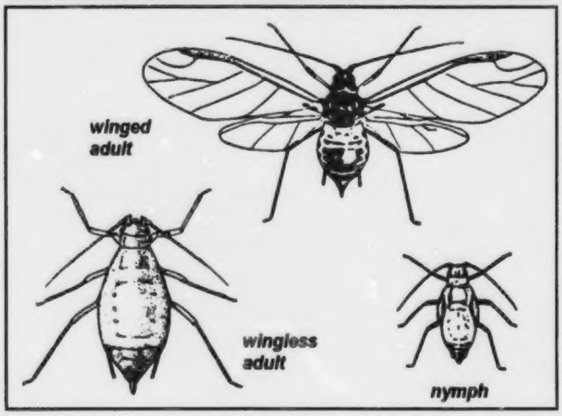
Description and Life History

Aphids are small (2–3 mm), soft-bodied insects with long legs and antennae. A pair of tube-like structures called cornicles project from the posterior end. Several species may infest greenhouses, with colour patterns ranging between black, gray, red, yellow, and green. The species most commonly found in greenhouse crops are the green peach aphid *(Myzus persicae)*, the cotton or melon aphid *(Aphis gossypii)*, and the potato aphid *(Macrosiphum euphorbiae)*.

Adult aphids are predominantly wingless, although winged adults can develop under conditions of high population density. This adaptation serves as a dispersal mechanism, allowing aphids to move into a greenhouse from outside, or to spread rapidly within a greenhouse.

In a greenhouse situation, all aphids are female and give birth to live young. These offspring can reproduce within 7–10 days. One aphid can give birth to 60–100 young over a 20-day period. Aphids can rapidly achieve very large populations.

FIGURE 4–5. Green Peach Aphid



Damage

- Aphids pierce plant tissue with their mouthparts and suck out the sap, causing deformed leaves and flowers.
- Aphids moult through a number of different stages before they become adults. The cast-off skins they leave behind each time they moult are a visible sign of their presence.
- They excrete a sugary, sticky substance called honeydew, which promotes the development of black, sooty mould fungus. Some aphids can transmit plant virus diseases, such as cucumber mosaic virus in cucumber crops.

Control Strategies

- When monitoring for aphids, catch winged adults on yellow sticky boards.
- For wingless aphids, you must inspect new foliage carefully and regularly to prevent large infestations.
- Spot treating isolated infestations can prevent their spread to the rest of the greenhouse.

- When infestations occur in the blossom stage, smokes may be more effective and less phytotoxic to plants.

Biological Control

- Several types of biological control agents are readily available: the predatory midge *Aphidoletes aphidimyza*, the parasitic wasp *Aphidius* spp., and ladybeetles (*Hippodamia convergens* and *Harmonia axyridis*).
- *Aphidoletes* and ladybeetles are usually used to supplement the activity of *Aphidius* and for reducing aphid populations in "hot spot" areas.

Aphidoletes aphidimyza

In the adult stage, *A. aphidimyza* resemble small mosquitoes or fungus gnats. Females lay up to 200 eggs in their lifetime. Eggs are laid close to aphid colonies, so the orange-coloured larvae have a readily available food source on hatching.

Larvae usually hatch after 2–3 days. After 7–14 days in the larval stage, they drop to the floor to pupate. The pupal stage usually lasts about two weeks. Adult *A. aphidimyza* feed on honeydew, and larvae can kill 3–50 aphids per day. Under natural day lengths, *A. aphidimyza* enters diapause between September and March—they are not effective during this period.

Aphidius spp.

This parasitic wasp does not enter diapause and is usually more effective during winter, early spring, and fall. During summer, other parasitic wasp species can parasitize *Aphidius* reducing their impact on aphid populations. Optimum conditions for *Aphidius* are 18°C–25°C and 80% RH. *Aphidius* completes its development from egg to adult in about 10 days at 25°C, and 14 days at 21°C.

Several species of *Aphidius* are commercially available. *Aphidius matricariae* can parasitize about 40 aphid species, including the green peach aphid, while *Aphidius colemani* is more effective against the cotton aphid but still works quite effectively against the green peach aphid. *Aphidius ervi* is the best choice against the potato aphid.

Hippodamia convergens

Both adult and larval ladybeetles feed on aphids. Larvae can feed on a total of about 400 aphids and adults on up to about 5,000 aphids each. Ladybeetles enter diapause under short-day conditions. When day lengths are suitable, ladybeetles must feed on aphids to maintain egg production. Eggs are torpedo-shaped and orange-coloured. They are laid in circular clusters on the underside of leaves, and hatch in 2–5 days.

The larval stage lasts for about three weeks, after which they pupate. Adults emerge from pupal cases after 3–5 days. To increase the percentage of ladybeetles remaining in the greenhouse, sprinkle a sweet liquid (e.g., diluted pop) over the beetles, and release them in late evening. The sweet liquid provides an immedi[illegible]ergy and water source.

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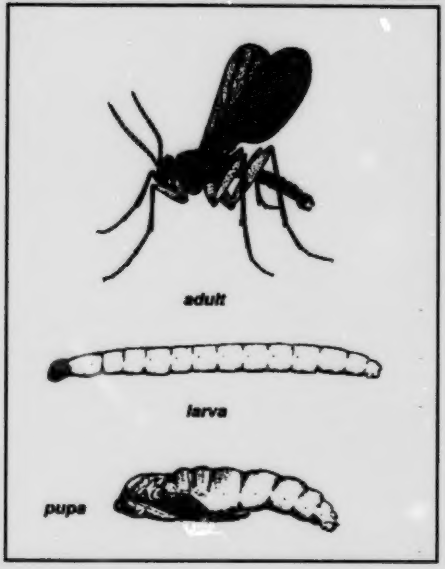
Fungus Gnats

Description and Life History

The gray to black adult fly is about 3–4 mm long with long legs, thread-like antennae, and large compound eyes that meet above the base of the antennae. The adult is a weak flier, frequently observed resting on the media surface. Each female lives about 10 days and lays about 150 oval, white eggs in the organic matter of the media. Eggs hatch in 2–7 days, depending on the temperature, producing white larvae that are 4–6 mm long.

The larvae have 12 abdominal segments and a distinctive shiny black head. The larvae spin pupal cases and remain immobile in the soil for 4–6 days, after which adult flies emerge. As with most insects, fungus gnats become more active and reproduce more quickly at warmer temperatures. The life cycle can be completed in 21 days at 24°C, compared with 38 days at 16°C.

FIGURE 4–6. Dark-Winged Fungus Gnats



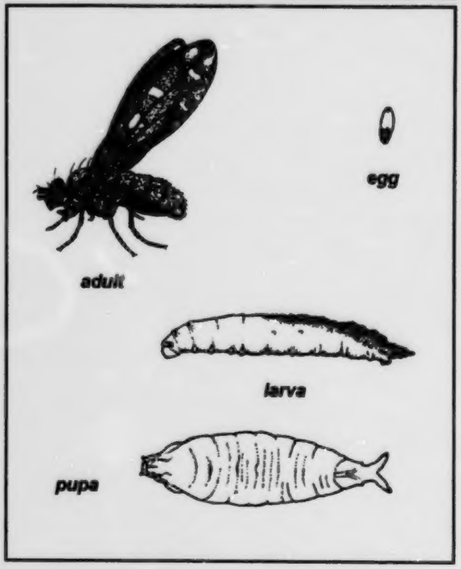
Shoreflies, another common greenhouse pest, are often confused with fungus gnats. The adults are stouter than fungus gnats, stronger fliers, and have four clear spots on the wings. The larvae live in soil, like fungus gnats, but lack the distinctive black head capsule. They are likely to prefer moister conditions than fungus gnats and are often found in wet areas under benches with both adults and larvae feeding on algae.

Shoreflies are not usually a threat to greenhouse crops, but can feed on roots in recirculating systems. Shorefly control requires controlling algae, either directly (by applying chemicals) or indirectly (by reducing moisture necessary for algal growth; or reducing the high light levels the algae need, perhaps by the use of blackout skirts around benches).

Damage

- Although fungus gnats generally feed on decaying organic matter in the soil, they can also feed on the young roots of plants. This is especially true when gnat populations are high.
- They have occasionally been observed feeding on the youngest shoots of cucumbers.
- Root feeding by fungus gnats makes a plant susceptible to root diseases such as *Pythium* root rot. Fungus gnats have also been implicated in the spread of disease-causing organisms such as *Pythium, Fusarium, Verticillium,* and *Rhizoctonia.*

FIGURE 4–7. Shore Flies



Control Strategies

- Sanitation inside the greenhouse and in the surrounding outside area is very important.
- Avoid overwatering and maintain good drainage to prevent water puddling—fungus gnats and shoreflies thrive in moist conditions.

Biological Control

Biological control agents include a predatory mite, *Hypoaspis miles,* and a parasitic nematode, *Steinernema feltiae.*

Hypoaspis

Hypoaspis is a soil-dwelling, brown mite that feeds on fungus gnat eggs and larvae, algae, thrips pupae, springtails, nematodes, and larvae of various flies and beetles. *Hypoaspis* is a hardy mite that can live about 24 days without food. It is not affected by low light conditions and has a life cycle of about 9–11 days under greenhouse conditions.

Hypoaspis is found mainly in the top 1 cm or on the surface of the plant media. It works best when applied to the media just after plants are potted up or vegetable seedlings planted out. *Hypoaspis* is most effective when fungus gnat populations are still low or nonexistent.

Nematodes

The nematode *Steinernema feltiae* is best used under higher population conditions. Nematodes enter the body openings of fungus gnat larvae, then release bacteria, which multiply and kill the larvae. Because nematodes are believed unable to multiply within the bodies of fungus gnat larvae, you must use several consecutive nematode applications to achieve control.

To use nematodes successfully:

- Shake nematode stock solutions every hour to incorporate oxygen into the water.
- Use the solution within 4 hours.
- Media temperatures should be 16–30°C.
- Never expose nematode suspensions to direct sunlight. This will destroy the bacteria within the bodies of the nematodes.
- Plant media should be pH 3–8.
- Check the compatibility or residual activity of fungicides before applying to media that have been, or will be, treated with nematodes.

Chemical Control

Soil drenches can effectively control the larvae.

Leafminers

Description and Life History

Two main species of leafminers affect Ontario growers: the vegetable leafminer *(Liriomyza sativae)* and the serpentine leafminer *(Liriomyza trifolii).* A third species, the pea leafminer, *Liriomyza huidobrensis*, which is a major pest in other parts of the world, has also been found in Ontario. Although the serpentine leafminer can complete development on tomatoes and cucumbers, it prefers chrysanthemum, gerbera, and gypsophila. Conversely, vegetable leafminer prefers tomato, cucumber, and celery, but will attack chrysanthemum and other plants in the absence of its preferred host. The pea leafminer has a wider host range and can move into field grown crops as well, including vegetable crops such as cole crops, lettuce, and celery. The three species of leafminer are similar in appearance and biology.

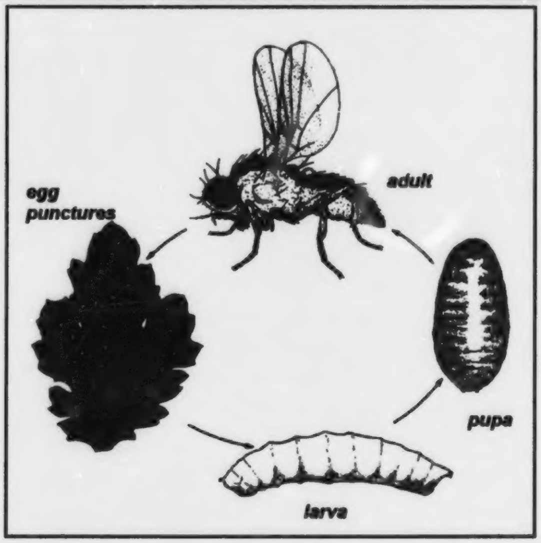
The adult leafminer is small (approximately 3 mm long), with black and yellow markings on the head and thorax. Adults become active at sunrise. Females feed on soft, succulent leaves by piercing the surface with their ovipositor, then lapping the liquid exuding from the leaf.

Female flies begin laying eggs 12–24 hours after emerging from the pupa. They lay about 250 eggs during their approximately 30-day lifetime. Eggs are laid in about one out of seven leaf punctures (or "stipples"). The optimal temperature for leafminer development is 30°C. At temperatures above or below 30°C, egg production/female declines considerably. After 2–4 days, eggs hatch, and the larvae begin feeding (or mining) in the leaf tissue.

The larvae mature in 4–7 days in summer, then cut a hole in the leaf surface, and drop to the ground. Pupation takes place within a few hours, in the plant media or on plastic sheeting (where used). Pupation can also occur on the leaves. The pupal stage may last 5–10 days in the summer, and up to 90 days during periods of low temperature (10°C–12°C) and scarce food supply. This may account for the winter survival of leafminers around the inside perimeter of the greenhouse, though no adult leafminers are evident. From the pupae, a new generation of adult flies emerges.

There is considerable overlapping of stages of the insect life cycle within any greenhouse. The complete life cycle of the leafminer can be 14 days at 30°C, 24 days at 20°C, and 65 days at 14°C.

FIGURE 4–8. Leafminer



Damage

- Leafminer feeding may indirectly affect yield by reducing the plant's photosynthetic area, and by damaging water-conducting vessels (causing leaf desiccation and leaf drop).
- By marring the appearance of ornamental crops, feeding damage by leafminers significantly reduces their economic value.

Control Strategies

- Inspect all new plant material entering the greenhouse.
- Destroy infested seedlings, cuttings, and plant parts.
- If growing in ground beds, steam-sterilize the entire greenhouse floor between crops.
- Monitor the crop for pests with yellow sticky boards and regular crop inspections.
- Get rid of weeds inside and outside the greenhouse. Weeds such as lamb's-quarter, chickweed, dandelion, plantain, common mallow, and nightshade are good hosts for leafminers.
- Don't over-fertilize the crop—excess nitrogen levels can increase leafminer problems.
- Detached leaves should be bagged and removed from the greenhouse as soon as possible. Leafminer larvae can complete their development in leaves even after they are removed from the plant.

Biological Control

Biological control agents include the parasitic wasps *Diglyphus isaea* and *Dacnusa sibirica. Diglyphus* is likely to be a better choice in summer, when its numbers may be supplemented by naturally occurring populations migrating into the greenhouse from outside. *Dacnusa* will perform better than *Diglyphus* over the winter.

Diglyphus isaea

Diglyphus is a small, black wasp with a metallic, green sheen and short antennae. After locating a mine, the female first paralyzes the leafminer, then inserts an egg through the leaf, placing it near the leafminer. It may deposit up to five eggs in this manner. The larva that hatches is initially colourless, then becomes yellow-brown, and finally turquoise. Development time from egg to adult is about 11 days at 25°C. This is generally shorter than that of both the leafminer and *Dacnusa.*

Diglyphus can parasitize leafminers already parasitized by *Dacnusa.* It becomes the dominant species during summer, when warm conditions favour their activity. Presence of short mines indicates *Diglyphus* activity, as the paralyzed leafminer stops feeding immediately.

Dacnusa sibirica

The adult is a small, black wasp that differs from *Diglyphus* in having long, flexible antennae and in lacking the metallic green sheen. Unlike *Diglyphus,* a female *Dacnusa* inserts an egg into the body of the leafminer. Each female lives for about 2 weeks, during which time she may lay up to 90 eggs.

Eggs hatch within 4 days, and the larvae mature within the leafminer pupae. Development time from egg to adult is about two weeks at 22°C. All Dacnusa development takes place within the leafminer's body; therefore, assessing parasitism is difficult.

Chemical Control

- Leafminers easily develop insecticide resistance.
- Ensure good pesticide coverage of the crop.
- Rotate pesticide classes every 2–3 weeks on crops for which registered pesticides exist. Currently, pesticide registrations exist only for ornamental crops.

Line drawings of insects in this section are used with permission from *Insect and Related Pests of Flowers and Foliage Plants. (1994). North Carolina Co-operative Extension Service, Ed. J. R. Baker.*

5. Occasional Greenhouse Flower Pests

Ants

Ants are easily recognized by their elbowed antennae and narrow waists. They range from 1.5–6 mm long.

- Ants are attracted to sweet substances. In greenhouses where insect feeding has produced honeydew, or where flowers have nectaries, ants may be a problem. Treat all ant trails or nests located in or near the greenhouse. Flooding nests with insecticidal soap and using household boric acid baits can provide some control.

Black Vine Weevil

Weevils (or snout beetles) have a hard body with a snout and elbowed antennae. This species is dull brown to black, about 9 mm long with fine ridges along the back. The larvae are legless grubs, white with reddish-brown heads, and are found among roots of various bedding plants.

- Adults actively lay eggs in June, and the larvae feed on the roots for the rest of the season. The larvae will attack a wide range of plants including rose, geranium, fern, gardenia, kalanchoe, and rhododendron. Although the adult does not fly, it can move to new plantings easily.
- Use control measures in late May and June. Inspecting the roots of all material introduced to the greenhouse may prevent an infestation.

Caterpillars

Several different insects have caterpillar stages that damage greenhouse crops. These include leaf rollers, armyworms, cutworms, loopers, fruitworms, hornworms, and leaf tier and stalk borers. The adult moths of these caterpillars are often attracted to greenhouse lights in the summer and will then lay eggs that hatch into the caterpillar pest.

- Armyworms and cutworms feed directly on plant foliage and may cause considerable damage. Both insects are dark brown or gray with longitudinal stripes. Cutworms burrow into the soil during the day and come out to feed at night.
- Use insecticides recommended for caterpillars to bring armyworm and cutworm infestations under control.
- Cabbage loopers commonly attack certain greenhouse crops such as alstroemeria between July and September. Cabbage loopers are green with faint white longitudinal body stripes.
- Stalk borers bore into plant stems, making them more difficult to control.
- Another damaging borer, the European corn borer, can infest many fruits before being detected. They normally begin infestations in spring around May to early June. There are two generations of this borer in southwestern Ontario, and one generation elsewhere in Ontario.
- Pheromone traps can be used to detect certain moth species, and light traps can be used to monitor many species.
- If you detect these pests early, begin control before the small caterpillars start feeding. Screened vents help prevent the entry of all caterpillars, and a good inside/outside weed control program will reduce potential infestation sites. Apply a bacterial insecticide, Dipel or Thuricide, for good control of loopers and most leaf-eating caterpillars that are not miners.

Grasshoppers

Grasshoppers are easily recognizable and occasionally invade greenhouses.

- They will feed on almost any vegetation and, in large numbers, can destroy plants.
- Grass and weeds near greenhouses may allow a grasshopper infestation to occur, usually in late summer and fall.

Mealybugs

Two distinct groups of mealybugs are found in greenhouses. The more common foliage-feeding mealybugs are white, wax-covered, scale-like insects with piercing mouthparts that remove plant sap.

- Mealybugs produce large amounts of honeydew. The females (1–3 mm long) lay large numbers of eggs in masses of wax. Active immature mealybugs called crawlers hatch from these eggs in 5–10 days. The nymphs mature into reproductive adults in 6–8 weeks.
- Damage is caused by the removal of plant sap, the growth of black, sooty mould fungus on the honeydew, and the unsightly appearance of the waxy secretions.
- Mealybugs are a serious greenhouse pest because the crawlers spread rapidly and exist under bud scales and within leaf axils. Males, present in low numbers, are small, winged insects.
- Occasionally, root-feeding or subterranean mealybugs are found, within masses of wax, on the roots of wilting or yellowing plants. These insects are much like those described above, but secrete less wax over their bodies.
- Inspect all plant materials entering the greenhouse carefully for the presence of mealybugs. The crawler stage of all mealybugs may spread to other plants through contaminated equipment or via water leaching through pots. Most infestations result from introduced contaminated material.
- Biological control agents for this pest include the Australian ladybeetle, *Cryptolaemus montrouzieri*, the common ladybeetle, *Hippodamia convergens*, and a parasitic wasp, *Leptomastix dactylopii*.
- Chemical control can be achieved with systemic granular and drench insecticides.

Midges

These small (1 mm), delicate flies lay eggs in the stems, leaves, or flower buds of ornamental plants. The larvae burrow into plant tissue, causing swellings of stems, galls on leaves, or collapse of buds.

- The rose midge is a concern to Ontario rose growers as it can quickly cause serious losses. Flower buds bend or become distorted, then turn brown and die. The rose midge is most abundant during the hot summer months, when it enters greenhouses from infestations on outdoor roses. Eggs hatch in approximately two days; larvae mature in 5–7 days, and drop to the soil to pupate in another 5–6 days. The adult midge then emerges and lives for only a couple of days.
- Pesticide sprays for the adult stage are ineffective. For ornamentals, use a foliar spray of the systemic Orthene to control larvae in the base of the buds, and a soil drench of Diazinon to control the larvae that fall to the soil surface.

Mites

Cyclamen Mite/Broad Mite

Cyclamen mites and broad mites are microscopic in size. They are no more than 0.25 mm long and cannot be seen without magnification. The hind pair of legs of the female is thread-like while those of the male are pincer-like.

- The pale brown female mite deposits approximately 100 eggs, 80% of them female, around the crown of the plant or along the midrib of unfolded leaves. The mites develop through the six-legged larval stage and quiescent nymphal stage with eight legs, similarly to the two-spotted mite. The life cycle from egg to adult is about two weeks but varies depending on the temperature.
- Distorted leaf tissue and/or small, blasted or twisted flower buds and flowers are usually the first damage symptoms. Foliage will often show purplish areas. The cyclamen mites feed around the crowns of plants or in the flower buds. Cyclamen is usually the most seriously injured, but many foliage, bedding plants, and other potted crops can also be attacked.

Tomato Russet Mites

The adult mite is 0.2 mm long and 0.05 mm wide. Because of its small size, the mite is not noticed on plants until it reaches damaging levels. At this time, the stems, leaves, and fruit appear beige or bronze as a result of the high mite population density.

- Russet mites appear to thrive under dry conditions. The life cycle lasts about six days at 27oC and 30% RH. Females can lay about 16 eggs during their lifetime of about three weeks. Russet mites feed first on stems, then on leaves.
- Damage symptoms include yellowing, curling, and wilting of leaves, flower abortion, and bronzed, cracked fruit. If not controlled, the tomato russet mite will eventually kill the plant.

- Alternative hosts for this pest include nightshade, petunia, and several other species of the tomato family.
- No early detection techniques exist for this mite. Once established in a crop, they easily spread by hands, equipment, and clothing.
- There are no current recommendations for biological control. Work to date indicates that two predatory mites, *Amblyseius fallacis* and *Typhlodromus occidentalis*, are potential biocontrol agents.

Scale Insects

Scales are minute, wingless insects up to 3 mm long. They have piercing/sucking mouthparts and an oval or hemispherical body shape. Scales secrete a characteristic waxy or scale-like covering over their bodies. Males, which are rare, have wings.

- Most scales are females that lay hundreds of eggs under their immobile scale. When these eggs hatch, the small crawlers migrate to new feeding sites. Damage is caused by the removal of sap from plants, resulting in yellowing, wilting, stunting, and distortion of plants.
- Several species have been identified on greenhouse ornamentals in recent years, mainly due to the increased amount of foliar stock being imported from tropical areas. Many newer introductions of fern, palm, and ivy plants are susceptible to scale infestations.
- To help control scale, quarantine, check, and treat or destroy infested material.
- Biological control agents for soft and armoured scales include two small ladybeetles, *Chilocorus nigritus* and *Lindorus lophanthae.*
- A small parasitic wasp, *Metaphycus helvolus*, has been reported to help manage several species of soft scales. Another wasp, *Aphytis melinus*, can be used for several species of armoured scales.
- Chemical control of scales includes the application of granular systemic materials and fog solutions.

Ivy Scale and Greedy Scale

These scales are similar in appearance, pale and circular with a prominent yellowish nipple in the centre. Both attack a wide variety of greenhouse plants such as ivy, palm, ficus, and fuchsia.

Fern Scale

The shield of this scale resembles an oyster shell. It is brown with a lighter terminal nipple and is usually found on ferns and other foliage.

Brown Soft Scale

Female scales are flat, brown, and pliable. They have a wide host range and produce large amounts of honeydew that promotes the development of black, sooty mould fungus.

Hemispherical Scale

The scale covering on this species is very convex, brown, and shiny. Ferns are a favourite host.

Slugs and Snails

Slugs are dark gray, soft-bodied creatures, 1.3–10 cm long. They glide over plants leaving a shiny trail. Slugs eat the foliage of most greenhouse plants, shredding the leaves, and they may completely destroy a plant.

- Snails are similar in colour and appearance to slugs, except that a snail bears a noticeable shell. The shell varies in colour and markings, and may be 1.3–5 cm in diameter. Snails are particularly injurious to seedlings. They eat holes in the flowers and leaves of many plants, leaving them shiny and tattered.
- Individual snails may lay up to 100 eggs, depending on the species. Slugs lay fewer eggs that may remain unhatched for long periods under dry conditions. They hatch upon return of moist conditions.
- Both slugs and snails need a damp environment and fairly humid air to survive. They avoid the sun and come out primarily at night or on cloudy days. During the day, slugs hide under boards and rocks or in other damp, shady places. If the air or substrate is dry, a snail can pull its entire body into its shell and remain dormant for up to four years.
- Some growers have reported good control of slugs by using certain parasitic nematodes.

Indirect control strategies for these organisms should focus on reducing their favoured habitat. These strategies include:

- Remove boards, bricks, etc. that are in contact with the ground, or arrange these to permit proper air circulation around and under them.
- Maintain a plant density that permits sunshine to penetrate to the ground level, provides good air-circulation, and allows the plant media to dry.

- Where a low plant density is inappropriate, use a ground cover unattractive to snails (e.g., rough-cut cedar chips or crushed eggshells).
- Sawdust and diatomaceous earth are an effective barrier if kept dry.

Various devices can trap or attract slugs and snails for subsequent destruction.

- Traps can be made using beer or a mixture of water and commercial yeast as an attractant.
- Inverted flower pots with crushed snails or slugs, or inverted grapefruit halves, are good devices for attracting slugs and snails.

Chemical controls involve baited pesticides that combine bran bait with metaldehyde.

- Metaldehyde is toxic and must be inaccessible to children and pets.
- Prolonged use of baits is likely to produce a local bait-resistant population.

Sowbugs/Pillbugs

Sowbugs and pillbugs have gray, flattened, oval bodies up to 13 mm long and have seven pairs of legs. Sowbugs have two small, tail-like structures that the pillbugs lack.

- They are both small decomposers but occasionally feed on roots and tender plant parts causing seedling damage. They feed at night and hide during the day, preferring dark, moist areas with abundant organic matter.
- Sterilizing soil and eliminating decaying plant material and moist areas will help prevent a buildup of these pests.
- Many strategies used for snail and slug control also suppress sowbug/pillbug populations.

Springtails

Springtails are tiny, wingless insects 2–6 mm long. They range in colour from white, gray, or yellow, to red, orange, purple, brown, or mottled hues.

- They are usually found on the surface of moist soil, in pots, or within the soil.
- They have a spring-like apparatus at the end of the abdomen that allows them to spring into the air.
- Most springtails are scavengers, feeding on decaying organic matter, algae, or fungi. Because they usually don't feed on living plant material, chemical controls are rarely necessary.

Striped Cucumber Beetle

Striped cucumber beetles are yellow-green beetles about 6 mm long. They have three longitudinal stripes. These beetles and a relative, the spotted cucumber beetle, carry the bacteria *Erwinia tracheiphila,* which causes bacterial wilt in cucumbers and related species such as melons and squash.

- Striped adult cucumber beetles overwinter outdoors under old leaves, old logs, or trash. They emerge the following spring, mate, and feed for several weeks, then lay orange-yellow eggs in the soil at the base of plants.
- Larvae usually hatch in 10 days, then feed on the roots of plants for 2–6 weeks. Fully grown larvae are about 9 mm long. Pupation takes place in the soil, and adults emerge after about one week. There is only one generation per year in Ontario.
- The adult beetles damage plants by chewing on leaves, stems, and fruits, but the greatest damage comes from the wilt-causing bacteria they often carry in their gut. The bacteria survive the winter in the gut of the overwintering beetles. In the spring, the beetles inoculate plants with the disease as they feed on the plant tissue.
- There is no control for the wilt once a plant is infected. Inoculated leaves generally wilt within 5–6 days, and the plant dies within two weeks. Striped cucumber beetles can also transmit cucumber mosaic virus.
- The best control comes from insect barriers installed over all greenhouse openings to exclude the adult beetles.

Symphylans

Symphylans are found under stones, in rotting wood, and in moist soil high in decaying organic matter. They are small white creatures resembling centipedes, with slender, long, white bodies (1–5 mm long), 10–12 pairs of legs, and long antennae. (Centipedes have 15 pairs of legs.)

- While centipedes are beneficial predators that prey on many insects, symphylans can feed on the roots

of plants. On many crops, damage shows as tiny black marks on the roots where a hemispherical piece of tissue has been scooped out. Injured roots become stubby, and the plant becomes stunted.
- Damage caused by symphylans to roots and root hairs provides entry points for root-rotting diseases.
- Steam sterilization of soil or heating of soil by solarization can help to reduce populations.

Tarnished Plant Bug

These bugs are about 6 mm long, yellow-brown, with piercing mouthparts. The adults and their green nymphs feed on many crop and weed species. They can be serious pests to greenhouse crops such as chrysanthemum, gerbera, cucumber, and pepper.

- Eggs are inserted into plant tissue, and the small nymphs complete their life cycle in about four weeks. They damage new growth by causing foliage distortion and dead or distorted flower buds. They are most active during the summer and in the late fall, and may gain access to the greenhouses from surrounding weedy areas.
- Tarnished plant bugs tend to appear in crops where pesticide use is minimal. Eliminating weeds that may serve as spring/summer hosts or overwintering sites will lower overall populations.
- Screening vents will help control this pest.

Tomato Pinworm

The tomato pinworm (TPW) is a semi-tropical pest that can infest tomato crops in Ontario. It inflicts damage by feeding on tomato leaves and fruit.

- Other suitable hosts for TPW are potatoes and eggplant. Weeds such as nightshade and its relatives may also serve as hosts.
- The adult is a small, light-brown moth about 6 mm long. It is generally more active at night, laying most of its eggs on younger leaves during the first few nights of activity. Newly hatched larvae walk on the leaf surface for a very short time before entering the leaf to start mining.
- There are four larval stages, the first two of which are spent in the leaf. The third and fourth stages may be found between two leaves knitted together, in a leaf that has been folded over, or inside fruits. Larvae characteristically enter fruits just beneath the calyx.
- Mature larvae may either remain on the plant or drop to the ground to pupate. On the ground, pupation usually occurs within the top 15 cm of soil. Tomato pinworms do not diapause. Their development continues year round, slowing during cold weather periods. Development time from egg to adult usually ranges between 28 and 70 days, depending on temperature. The life cycle is completed in 28 days at 24°C, and can be as short as 19 days at 30°C.

Control strategies include:

- Inspect all seedlings for larval feeding damage.
- Destroy all old infested plants and any debris from infested crops.
- Monitor for the presence of tomato pinworm with pheromone or light traps, and by inspecting crops regularly. Note that pheromone traps attract only male TPW, whereas light traps attract both sexes of TPW and many other insect species.
- Hand-pick damaged leaves and destroy larvae within the mines.
- Destroy weeds and stray tomato seedlings inside and around the greenhouse.
- Install insect barriers over vents.

Vertebrate Pests

Rats and mice may be very destructive in the greenhouse. They feed on almost any food source and can cause damage by gnawing and burrowing.

- Norway rats and field mice are the most common vertebrate inhabitants of greenhouses. Baits containing rodenticides such as chlorophacinone, diphacinone, warfarin, and zinc phosphide can give some control. The first three chemicals are anticoagulants, and multiple doses are usually required. Zinc phosphide is not an anticoagulant and is more acutely toxic—a single dose can achieve kill.
- Ensure that the toxic baits are placed in covered stations where pets and children cannot get them.

To minimize the development of rodenticide resistance, particularly to the anticoagulants, always adopt other control measures:

- Store all potential food material in tight-fitting containers.
- Use many traps where there are signs of activity, placing one trap every 2–3 metres along walls.

- Set traps at right angles to the wall, with the bait and trigger facing the wall.
- Handle traps with gloves to avoid contaminating them with human smells.
- Try different baits. Suggested baits include peanut butter mixed with oats, raisins, gumdrops, or any other sticky food material, and cotton (which provides nesting material).
- Maintain several female cats as biological control agents. Female cats tend to be more predacious than males.

Root Nematodes

Plant parasitic nematodes are small (<1 mm long) worm-like organisms that live in the root media. They are broadly divided into two groups—ectoparasites (which attack plants externally) and endoparasites (which spend at least part of their life cycle within the plant tissue).

- All parasitic nematodes have stylets through which they inject saliva into the plant tissue. The saliva causes most of the damage. It results in necrosis or the proliferation of giant cells that produce galls.
- Nematodes cause damage mainly by reducing the ability of plants to absorb water and nutrients. Aboveground symptoms of nematode damage include weakened plants that wilt in the sun, yellow or pale green leaves, and stunted fruit or flowers.
- Where nematocides are used between crops, nematode infestations often recur because of insufficient penetration of the chemicals into the lower soil levels. Soils so treated should always be properly aerated to avoid subsequent plant damage.

Root-Lesion Nematode, *Pratylenchus penetrans* (Cobb)

This endoparasitic nematode is native to Ontario soils and can attack many floral and vegetable crops.

- All stages are thread-like and invisible to the naked eye.
- This nematode invades the outer layers of young roots, causing small brown-to-black elliptical lesions that merge to discolour the roots and kill them.

Northern Root-Knot Nematode, *Meloidogyne hapla* (Chitwood)

This is another endoparasitic nematode native to Ontario soils. It attacks almost all types of vegetable crops and many floral crops, particularly rose, African violet, and geranium.

- Early larval stages are thread-like and invisible, while later stages and adults are peanut- to pearl-shaped and just visible when dissected from roots.
- This nematode invades roots and settles down to cause swellings, knots, or galls, and excessive root proliferation. Infested roots do not necessarily become discoloured unless attacked by bacteria and fungi.

Dagger Nematode, *Xiphinema diversicaudatum* (Micoletzky)

This ectoparasitic nematode is not native to Ontario and was introduced into greenhouses on plant stocks. Dagger nematodes prefer plants with woody roots and are more frequently associated with crops such as strawberry, grape, and rose.

- The nematode survives in the root crotches of the understock.
- One of the largest nematodes attacking plants, this 6-mm long, thread-like roundworm can, with care, be seen on the roots. It feeds on young roots from the soil, causing galls similar to root-knot galls but somewhat larger. These galls are actually curved swellings in the root tip area, accentuated with the necrosis and shriveling of roots above the galls.

Pin Nematode, *Pratylenchus projectus* (Jenkins)

This nematode is native to Ontario and can attack many floral and vegetable greenhouse crops, especially roses. All stages of pin nematode are thread-like and invisible to the naked eye.

- This species is active in both fine-textured (clay) and coarse-textured (sandy) soils.
- The pin nematode does not enter roots but feeds at root tips by probing root hairs and surface cells. No specific root symptoms (such as galls or lesions) appear. Plants infested with this nematode show general aboveground symptoms.

Southern Root-Knot Nematode, *Meloidogyne incognita* (Kofoid and White)

This endoparasitic nematode is not native to Ontario but has become persistent in the protected greenhouse environment. It cannot survive outdoors during winter. It is a problem on tomato and cucumber but can also attack several floral and foliage crops.

- Root damage and symptoms differ from those of the northern root-knot nematode. Plants damaged by the southern root-knot nematode have larger galls and lack fine root growths from the galls.
- Tomato leaves may show phosphorus deficiency (purpling) on the underside, or downward curling of leaf edges; affected tomato or cucumber plants wilt readily.

Foliar Nematodes

A few nematodes attack plant foliage. Symptoms caused by leaf-feeding nematodes are similar to those of several diseases and nutrient deficiencies.

Strawberry Bud Nematode, *Aphelenchoides fragariae* (Ritzema Bos)

This nematode is not native to Ontario, but was introduced on plant stock. It is primarily a problem on begonia but can attack other greenhouse ornamentals.

- Invisible and thread-like, it moves in moisture films on stems and leaves.
- It enters leaves through the stomata and feeds in the inner layers of the leaf, causing small brown spots with water-soaked margins on the underside of leaves. The spots subsequently enlarge and merge, turn dark brown, and become visible on the upper surface. Finally, the entire leaf is affected.

Chrysanthemum Nematode, *Aphelenchoides ritzema-bosi* (Shwartz)

This nematode is not native to Ontario but was introduced on plant stock. It is almost identical to the strawberry bud nematode and moves and infests plants in the same manner.

- Early symptoms include dark-brown spots on the underside of leaves and vein discolouration.
- Infested leaves eventually turn brown or black, forming distinct wedge-shaped areas between the veins. Finally, the leaves dry, shrivel, and hang down along the stems.

Cultural control measures for minimizing nematode problems include:

- Use soil-free media or steam-sterilized media.
- Ensure that transplants are vigorous and free of root-galls or lesions.
- Use nematode-resistant or nematode-tolerant cultivars, or use nematode-resistant rootstocks where applicable.
- In soil-grown vegetable crops (e.g., tomatoes and cucumbers), mounding peat or sterile soil at the plant bases to stimulate adventitious root growth can help extend the productive life of the plants.

6. Integrated Flower Disease Management

Proper integration of disease prevention practices into the total crop management plan is critical to the health of your crops and the profitability of your business.

The basic objectives of any program should be to achieve at least the following:

1. Reduce the possibility of introducing diseases into the crop.
2. Avoid creating conditions suitable for disease establishment and spread.

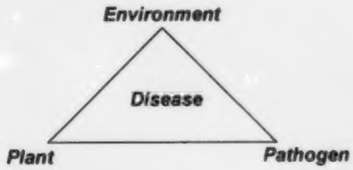
Disease control strategies are based on a few essential, universal principles and concepts. A sound disease management program for any greenhouse crop integrates these universal principles and concepts into the overall production system for that particular greenhouse crop.

It is important to understand the concepts of disease control, and the strategies developed from them, to make modifications appropriate for your particular greenhouse or crop situation. A disease control program involves more than a fungicide spray or drench schedule for the various crops grown. Too often, fungicide applications address the symptoms, not the problem.

The Disease-Triangle Concept

Three factors are necessary for disease development:

- A pathogen or disease-causing organism (e.g., a fungus or a bacterium).
- A susceptible plant for the pathogen to infect.
- A suitable environment in which the first two will interact.



For example, Thielaviopsis basicola will attack poinsettia when air and media temperatures are cool (15–17ºC), the media pH is high (above 6.5), and the sanitation is generally poor.

The environment includes both the soil or media environment in which the roots grow and the aboveground environment above ground where shoots, leaves, and flowers are produced.

Soil or media environment characteristics that must be considered include:

- pH
- nutrient levels and their balance
- EC
- moisture-holding capacity
- drainage
- oxygen content

Aerial environment characteristics that must be considered include:

- light levels
- temperature
- air movement
- relative humidity
- air quality

Six Principles for Plant Disease Control

Exclusion

- Preventing pathogens from becoming established in the greenhouse is a primary aspect of disease control. For example, geranium propagators use this principle each year when they purchase new virus-indexed/pathogen-free cuttings for stock plant production. This minimizes the potential for fungal and bacterial infections such as geranium rust or bacterial wilt.

- Growers who use soil or compost in their media pasteurize the material to eliminate soil-borne pathogens. Using new clean pots, cell packs, and flats helps prevent potential infestations of newly planted crops.

Avoidance

- This involves using common-sense practices to avoid situations that promote disease development. For example, growers should not use overhead watering late in the day, which creates conditions favourable for the development of *Botrytis*.

Resistance

- This involves the inherent ability of a host plant to remain healthy or resist attack, even though a pathogen is present and/or the environment is conducive to pathogen development. For example, most new tomato cultivars are being developed with genetic resistance to *Fusarium* crown and root rot.

Protection/Prevention

- Systemic fungicides can be applied before any disease is observed. These often protect crops during periods when conditions are conducive to disease development.
- For example, Exotherm Termil Smokes used at the end of the poinsettia crop can protect the bracts from *Botrytis* infections, and routine media drenching of cyclamen crops can protect against *Fusarium* crown rot.

Eradication

- Plant pathogens can be eliminated via several means, such as steam pasteurization of ground beds or rock-wool slabs, to eliminate root-borne diseases and nematodes. Sanitizing products such as chlorine bleach or quaternary ammonium chloride compounds can effectively control bacteria or fungal spores in dust or on benches and tools used for propagation or production.
- Plant breeders and primary propagators routinely index and tissue-culture vegetatively propagated plants to eliminate potential plant-infecting bacteria and viruses.

Therapy

- This involves treating infected plants. For example, Meltatox is sprayed on rose foliage to kill the mycelium of the powdery mildew fungus. This prevents further sporulation and spread of the fungus.

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Basic Integrated Disease Control Strategies

Environmental Manipulation

Environmental manipulation includes not only air temperature and relative humidity but also media composition, pH, EC, temperature, light levels, and air circulation.

- Know and understand the conditions required for the optimum growth of the crop and for the common diseases of that crop.
- Avoid extremes in relative humidity conditions. This minimizes the time period and conditions suitable for *Botrytis* or powdery/downy mildew to develop.
- Avoid poor air circulation within the greenhouse. This can cause uneven temperatures throughout the crop. It can also lead to free moisture forming on the plants, particularly at night, creating ideal conditions for mildew and *Botrytis* infections.
- Avoid *all* extremes, as much as possible, for the crops being grown. For example, the combination of high temperature and over-fertilization promotes *Fusarium* crown and root rot in cyclamen, while the combination of high temperature and high relative humidity is favourable to *Rhizoctonia* attacking cuttings during or just after propagation. Low temperatures should also be avoided to prevent outbreaks of *Pythium* in warm temperature crops.

Modification of Cultural Practices

Chronically stressing plants makes them more susceptible to attack by disease pathogens. Plants are stressed when the root and/or shoot environments are neglected.

- Understand the growing requirements of the crops being produced. Not all crops will tolerate the same conditions. Think about whether the crop being grown tolerates, say, constantly wet media. For example, Easter lily and primula require very different root management; lily roots cannot tolerate being overly wet and starved for oxygen.
- Monitor the media or substrate pH and EC every week.

- Avoid fertilization when soluble salts are high. The definition of "high salts" varies with the crop and its stage of development. High salts damage root hairs and young roots. These wound sites become entry points for disease pathogens.
- Use clean containers and porous, well-draining media to minimize the potential for pathogens such as *Pythium* and *Phytophthora*.
- If foliar diseases are an ongoing problem, review temperature, relative humidity, air circulation patterns, and watering practices.

Sanitation and Roguing

Keep the greenhouse free of weeds that may harbour diseases like Impatiens necrotic spot virus/tomato spotted wilt virus (INSV/TSWV) or insects that can be vectors of disease or virus.

- Disinfect propagating benches and trays before propagating to eliminate bacteria and fungi.
- Use expanded metal benches for ease of cleaning and to minimize the spread and survival of pathogens
- Steam traditional propagating benches regularly.
- Remove diseased plants from the greenhouse when first detected and discard properly by placing in a plastic bag and removing from the greenhouse.
- Wheelbarrows or soil carts used to discard diseased material should be dedicated strictly for disposal purposes. If this is not possible, disinfect after every use.
- Employees should wear disposable gloves when handling diseased plant material. If gloves weren't worn, employees should wash their hands before performing another function. They should also wash their hands between cultivars when taking cuttings.
- Dip cutting knives in 70% alcohol to prevent the spread of disease.

Pathogen-Free Plant Material

Purchase cuttings from specialized propagators or from the plant breeders to minimize the chance of introducing diseases into your greenhouse operation.

- If possible, isolate new plant material to reduce the potential for contamination.
- Change stock plants regularly. This may mean yearly or every 6 months, depending on the crop.
- Don't bring in clean stock until the old has been moved out and the area thoroughly sanitized. Alternatively, isolate the clean stock in a separate area.

Vector Control

Many viruses and viroids are spread by insects. For example, aphids spread Aster Yellows in chrysanthemums while TSWV/INSV is transmitted by western flower thrips.

- Consider using screening on open cooling vents to block many insect pests from the greenhouse. This makes control of the insect population easier.
- Fungus gnats are now known to spread the spores of *Pythium*. The larvae damage young roots through feeding activity. Research has shown that *Pythium* oospores (thick-walled sexual spores) are routinely transmitted through the gut of fungus gnat larvae. As well, the adult can transfer the pathogen with its legs and mouthparts.
- Controlling algae growth and providing adequate drainage under benches helps control insect populations and minimize the spread of disease pathogens.

Host Plant Resistance

Some cultivars of crops are less susceptible to certain diseases than others. Plant breeders are beginning to use gene manipulation to introduce disease resistance into crops.

Chemical Control

Fungicides have been the conventional approach to disease control. The role of fungicides can vary from protecting healthy plants to treating infected plants and eradicating diseases.

We will need to rely less on fungicides in the future. Fewer effective fungicides will be available, and environmental contamination concerns will increase.

Biological Control

Biological disease control involves the use of fungi and bacteria that strongly suppress disease-causing organisms and diseases without harming the crop. For example, researchers at the University of Guelph are studying several fungal isolates found in nature to control *Botrytis*. These are very effective on a wide spectrum of greenhouse crops.

Other commercial interests are testing beneficial fungi for the control of *Rhizoctonia solani* and *Pythium ultimum*.

As with pesticides, biocontrols will not be a universal panacea for disease control.

Success Criteria

- Monitor crops weekly or (at the least) biweekly to provide critical input to your decision-making process.
- Emphasize prevention rather than cure.
- Walking the crop(s) is essential to early detection. This means checking the crop foliage and root systems and both manual and computer-controlled environment conditions.
- As a grower/manager, keep detailed records that enable you to merge cultural, environmental, and insect and disease data for analysis.
- Include weather data to help anticipate potential disease problems. For example, a cool, cloudy, and wet summer with the central heating system off creates ideal conditions for downy mildew development. Poinsettia propagators can anticipate slow, uneven rooting and increased *Botrytis* rot if supplementary heating is not provided.
- The person in charge of monitoring cannot work in a void. He/she must work closely with the person responsible for overall crop scheduling. The person in charge of growing should be doing his/her own monitoring for disease and environmental control. In many operations, this should be done by an employee, not by the owner/grower.
- Correct diagnosis is crucial. You cannot achieve control using cultural or chemical strategies without correctly identifying the pathogen. Soil-borne fungi are the most difficult pathogen for growers to identify.
- Develop a thorough understanding of the diseases that affect the crops being grown. Correct use and timing of management strategies then becomes part of an ongoing process.
- Because disease pathogens are microscopic, learn to anticipate when possible pathogen infection periods are likely to occur. By the time the problem is visible, the pathogen has usually been present for some time and is more difficult to control.

7. Major Greenhouse Flower Diseases

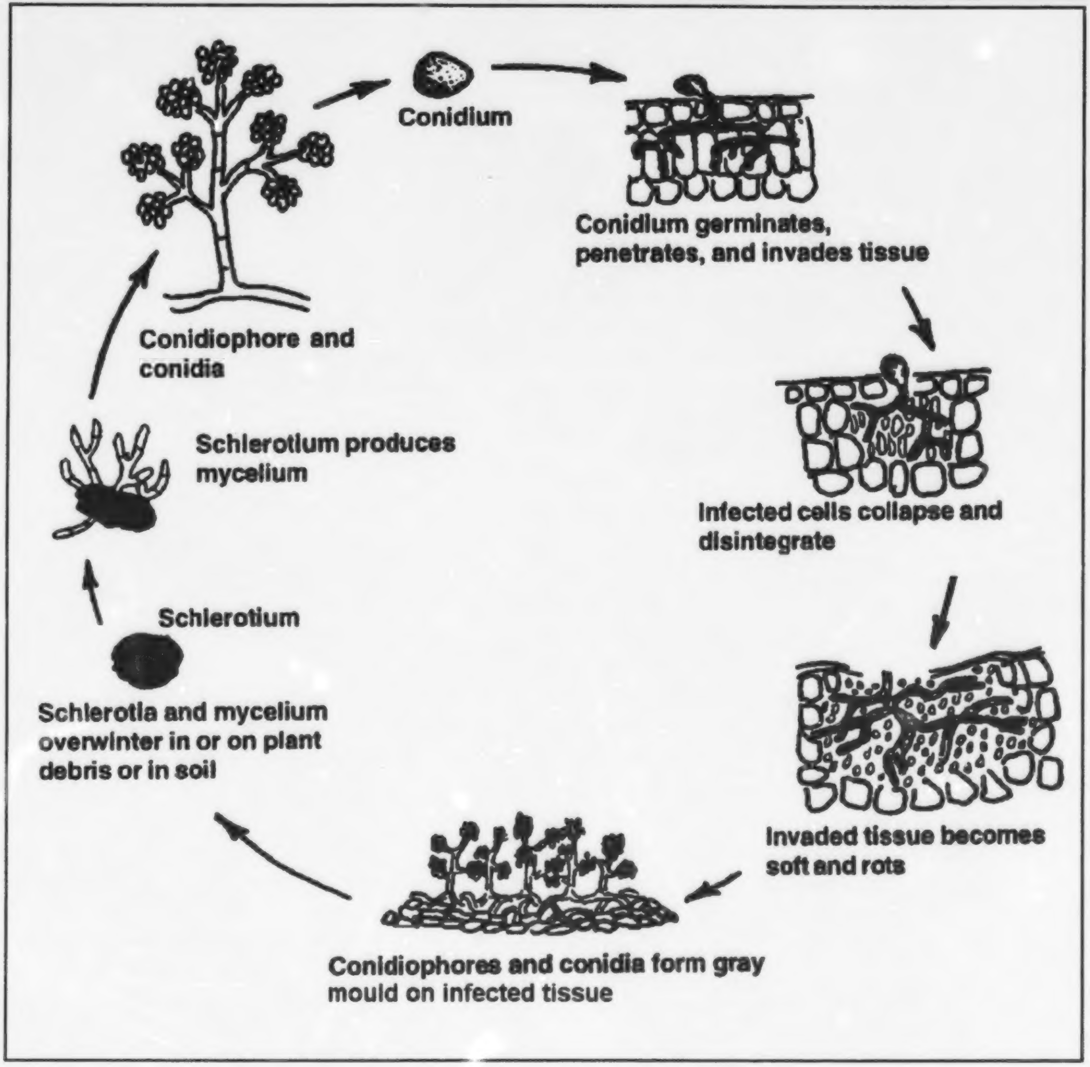
Fungus Diseases

Botrytis (Gray Mould)

This group of fungi, known collectively as *Botrytis cinerea,* causes many common diseases of greenhouse ornamental and vegetable crops. "Gray mould" is often used to describe the disease because of the prolific sporulation of gray or brown spores that occurs on infected tissues under appropriate conditions.

- *Botrytis* disease symptoms appear as flower spotting and blight, leaf blights, stem cankers, and corm or bulb rots.
- Infections occur when germinating conidia (spores) penetrate healthy succulent leaf or flower tissue, stomata, or wounds, or when pieces of fungal mycelium grow on dead or dying plant tissue in contact with healthy host tissue.
- *Botrytis* readily attacks healthy or senescing soft, nutrient-rich flower or bract tissues of cyclamen, geranium, rose, or poinsettia. Mycelial infections typically occur when infected flowers or leaves fall onto healthy tissues below and become appressed to wet leaf surfaces.
- Latent infections occur as described above but show no visible symptoms because of unfavourable environmental conditions. When environmental conditions change, symptoms may appear. This typically occurs with cut flowers, which appear healthy when packed but have tan-brown spots on the petals when unpacked.
- *Botrytis* is ubiquitous—the spores are always present. The conidia disperse very readily in air currents and in/on water droplets. Fluctuating relative humidity levels trigger the release of spores. Spore germination can occur in less than 3 hours, with sporulation occurring in 8 hours.
- *Botrytis* infections usually occur in cool, wet or humid, weather conditions. These conditions favour infection and sporulation. Free moisture containing dissolved nutrients acts with temperature to determine the initial infection and subsequent lesion development.

FIGURE 7–1. Botrytis Life Cycle


Conidium
Conidium germinates, penetrates, and invades tissue
Infected cells collapse and disintegrate
Invaded tissue becomes soft and rots
Conidiophores and conidia form gray mould on infected tissue
Schlerotia and mycelium overwinter in or on plant debris or in soil
Schlerotium
Schlerotium produces mycelium
Conidiophore and conidia

Disease Control

- *Botrytis* is often considered a "disease of bad management."
- Control it with crop management techniques and manipulation of the greenhouse environment. For example, reduce the relative humidity by maintaining warmer night temperatures and proper ventilation practices.
- Use computer-controlled humidity monitoring programs.
- Air circulation is critical for maintaining dry plant surfaces and usually depends on proper plant spacing. It helps to open plant canopies by removing excessive foliage.
- Sanitation before and during crop production is essential. Remove senescing flowers and leaves.
- Avoid overhead watering wherever possible. When overhead watering is necessary, water early in the day. This allows foliage and the canopy to dry before evening.

Fungal Leaf Spots, Flower Spots, and Blights

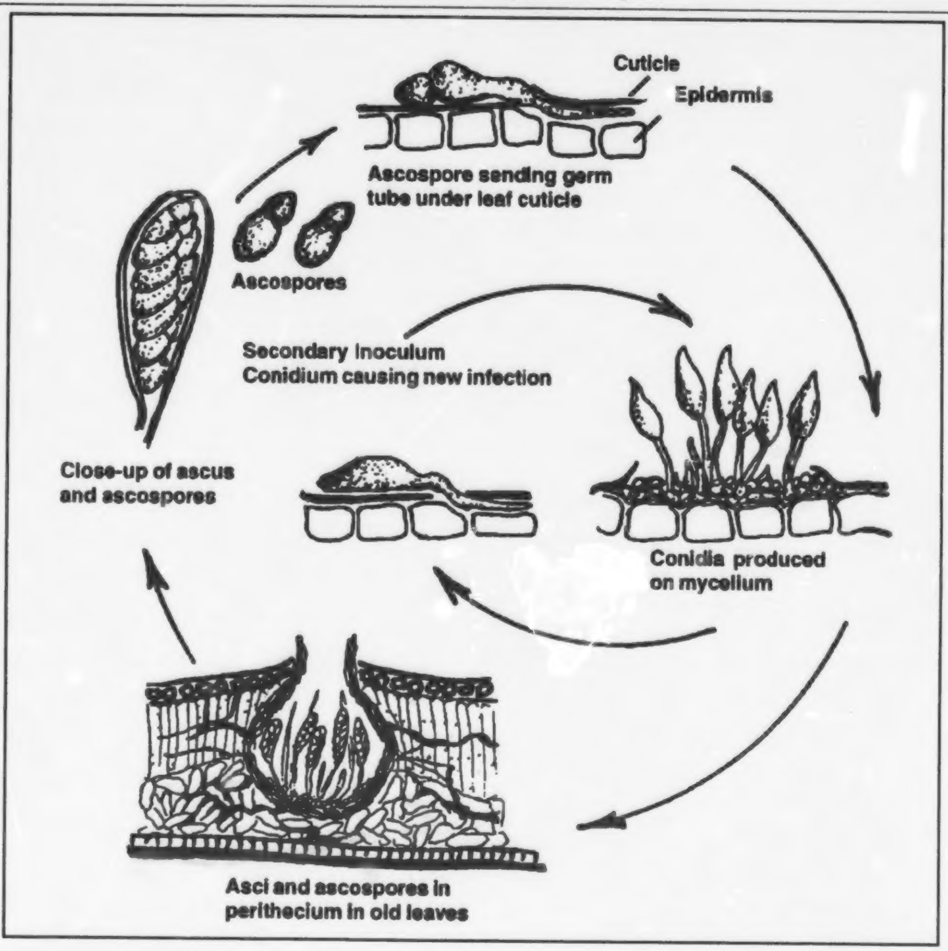
All of these diseases are caused by fungi, with symptoms varying greatly.

- Blights or spots can appear on leaves, stems, or flowers depending on the organism present. Many attack all three plant parts, but none attacks the roots or crown.
- Leaf blights and spots usually appear on the lower foliage and work their way up through the plant

canopy. Many of the pathogens produce characteristic spots or lesions, such as "bull's-eye" spots with a reddish border or tan-coloured spots with concentric rings. Spots may be circular, angular, or irregular.

- The more common fungi-causing leaf spots include *Alternaria, Ascochyta, Cercospora, Phyllosticta, Gloesporium, and Septoria*. Most produce abundant conidia. Spores of these fungi are wind-borne and can be splashed about when watering.
- Leaves must be wet for infection to occur.

FIGURE 7–2. Leaf Spot Life Cycle


Cuticle
Epidermis
Ascospore sending germ tube under leaf cuticle
Ascospores
Secondary inoculum
Conidium causing new infection
Close-up of ascus and ascospores
Conidia produced on mycelium
Asci and ascospores in perithecium in old leaves

Disease Control

- Keep foliage and flowers as dry as possible.
- Avoid overhead watering.
- Provide good air circulation.
- Remove infected plant material from the greenhouse.
- Use disease-free propagating material.

Powdery Mildew

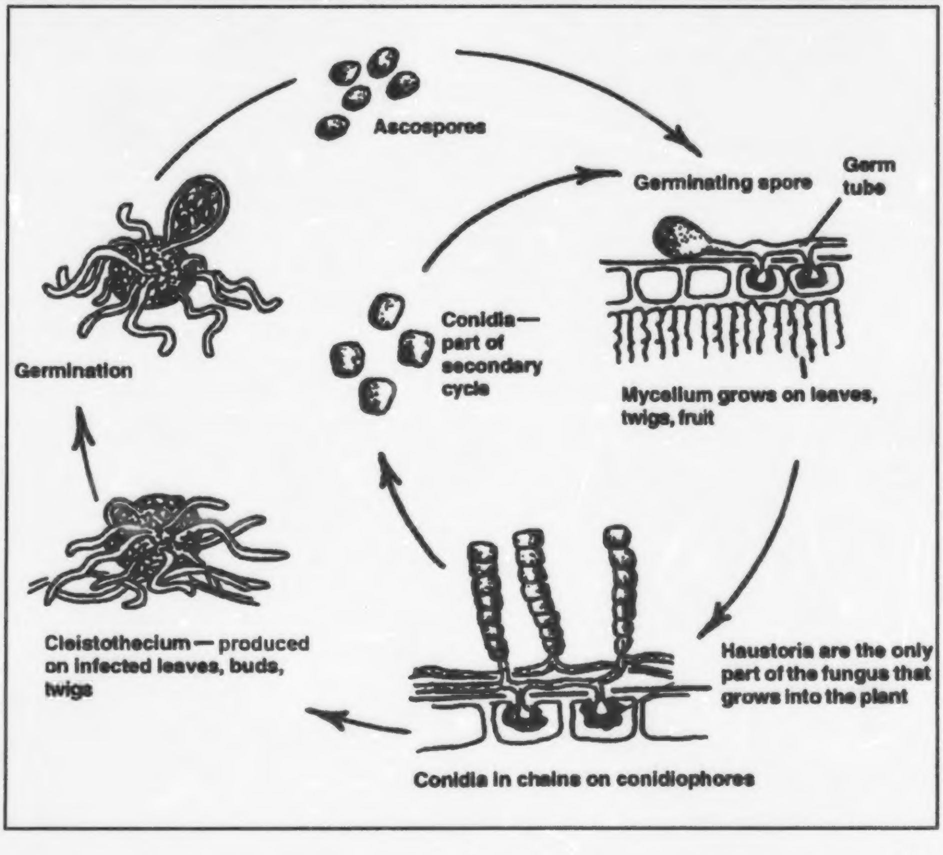
This fungal disease causes an easily recognized white powdery growth on leaves, stems, and floral parts of infected plants. The powdery mildew fungus that affects one crop generally doesn't affect others.

- The growth may begin as small, discrete spots but can spread to cover the entire upper surface of the leaves. On many plants, the fungal growth becomes felt-like. This happens when ideal conditions produce abundant superficial mycelia bearing many colourless conidia (spores). In some plants, the leaves develop a reddish discolouration where the infection occurred.
- Severe infections will cause leaf stunting, yellowing, and curling.
- In the greenhouse, powdery mildew fungi have a simple life cycle. Single-celled conidia form in a long chain on short, erect fungal stalks. This creates

the "fluffiness" usually associated with powdery mildew. Under favourable environmental conditions, conidia chains are produced and released; usually one conidium/day or diurnal cycle. Conidia mature and are ready for release in 24 hours. A relative-humidity drop and the heating/drying effect of solar radiation promote spore release.

- Conidia need relative humidity of 95% or more, for 3–4 hours, to germinate and penetrate the host's leaf or stem epidermal cells. There conidia produce a nutrient peg, which provides a constant nutrient supply for fungal growth. The fungal mycelium grows only on the leaf surface, regularly producing nutrient pegs and conidial stalks. Within 48 hours of inoculation, mature conidia can release to infect other leaves or plants.
- The severity and spread of powdery mildew infections are affected by relative humidity, temperature, light, leaf wetness, and air movement. Because of these interrelated environmental factors, you must use an integrated approach.
  - Excessive and turbulent air movements, such as drafts near open doors, promote infection and spread.
  - The powdery mildews attacking greenhouse crops need near 100% relative humidity or a near-zero vapour-pressure deficit to germinate.
  - Leaf wetness episodes promote fungal development.
- The occurrence and persistence of leaf wetness are affected by leaf-to-air temperature gradients, the degree of leaf radiant energy loss, solar radiation, and leaf transpiration

FIGURE 7–3. Powdery Mildew Life Cycle


Ascospores
Germinating spore
Germ tube
Mycelium grows on leaves, twigs, fruit
Haustoria are the only part of the fungus that grows into the plant
Conidia in chains on conidiophores
Cleistothecium — produced on infected leaves, buds, twigs
Germination
Conidia— part of secondary cycle

Disease Control

- Avoid drafts by keeping walkway doors closed. Automate the opening and closing of doors if possible.
- Maintain smooth airflow patterns over leaf surfaces. This prevents localized high relative-humidity areas and reduces air and leaf temperature fluctuations.
- Use a humidity-control program. Establish reasonable parameters and use an environmental computer to maintain the desired relative-humidity levels through ventilation and heating.

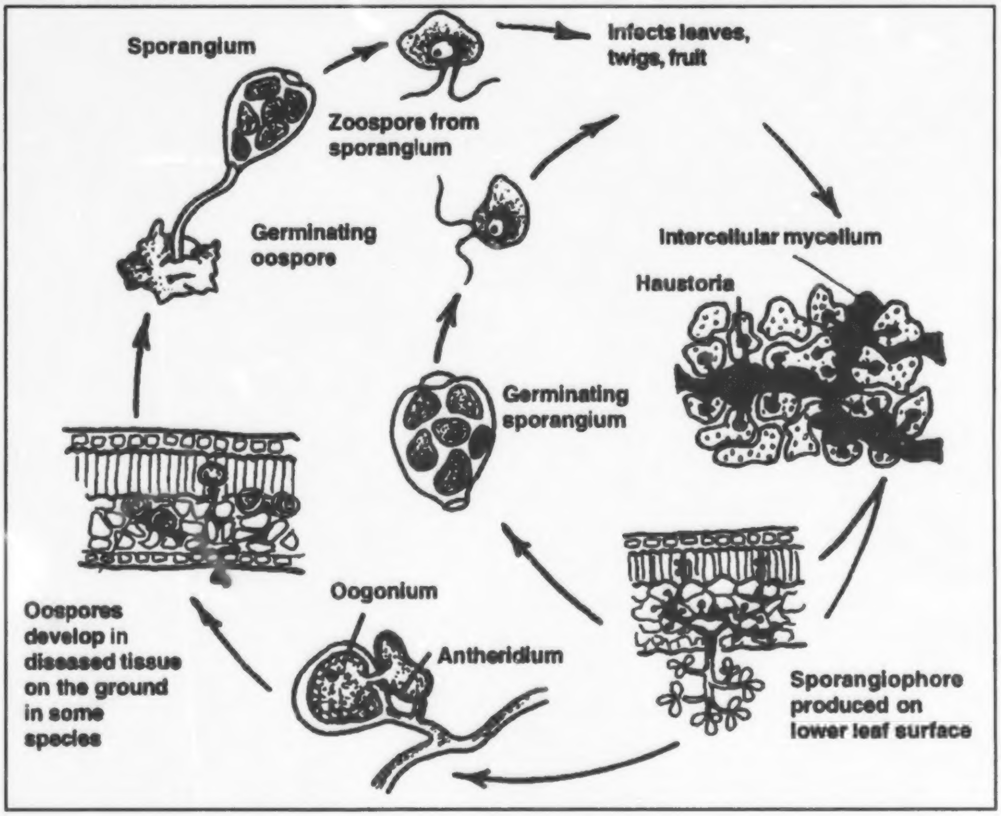
- Use crop-zone radiant heating to maintain a drier, warmer crop environment.
- Closing of shading/energy curtains and/or using high pressure sodium lighting will help prevent radiant energy loss from leaf surfaces.

Downy Mildews

These *Peronospora* fungi are primarily foliage blights. They attack and spread rapidly in young, green tissues, affecting foliage, stems, and flower buds of rose, snapdragon, and viola.

- Their development and spread depend on the presence of water films on the plant tissues and on high relative humidity during cool periods (but not during hot periods).
- Rose leaves develop purplish-red spots on upper leaf surfaces. They may be distorted, have symptoms typical of pesticide phytoxicity, turn yellow, and abscise in great numbers.
- Snapdragon foliage becomes distorted. If infection occurs in the seedling stage, it quickly becomes systemic and infects the growing tip or developing flower spike. Losses are severe.
- Downy mildew differs from powdery mildew in that the spores are produced on the undersurface of the leaves. Depending on environmental conditions and the downy mildew species, the number of spores produced can vary significantly.
- Downy mildew of snapdragons produces masses of gray-brown spores that look like thick velvet.
- Rose downy mildew produces very few visible spores unless optimal conditions exist.
- Sexual reproduction causes oospore production, which carries the fungus through periods unfavourable for vegetative growth.

FIGURE 7–4. Downy Mildew Life Cycle


Sporangium
Zoospore from sporangium
Infects leaves, twigs, fruit
Germinating oospore
Intercellular mycelium
Haustoria
Germinating sporangium
Oogonium
Antheridium
Oospores develop in diseased tissue on the ground in some species
Sporangiophore produced on lower leaf surface

Disease Control

- Most control comes from proper environmental manipulation.
- Control the relative humidity to prevent moisture condensation on the plants.
- Balance the heating and ventilation.
- Avoid wetting the foliage when irrigating.

- Clean up all crop debris and infected plants and remove everything from the greenhouse, as the organism survives between crops on dead plant material.
- Many epidemics begin during cool, damp weather, affecting growers who don't have a heating system or who attempt to economize on fuel consumption.

Wilts

- Wilt diseases cause a whole plant, a portion of a plant, or a major branch to wilt. Other symptoms include vascular discolouration, stunting, and varying degrees of leaf yellowing. Infectious wilts divide into two broad categories:
    - Fungal, caused by *Fusarium solani*, *Fusarium oxysporum*, and *Verticillium albo-atrum*
    - Bacterial, caused by *Erwinia chrysanthemi*, *Erwinia carotovora*, *Xanthomonas campestris*, and *Pseudomonas solanacearum*
- Most fungal wilt pathogens are soil-borne, attacking through roots or the crown area.
- Root hairs and root tips exude nutrient-rich chemicals into the media. These are the first nutrient source for potential pathogens. Bacterial pathogens also need a wound or natural opening (such as stomates or hydathodes of leaves) for invasion.
- Fungal wilt pathogen growth is limited to the vascular tissue, while bacterial pathogens spread rapidly into adjacent tissues. Both groups of pathogens can be carried in the stems of symptomless cuttings.
- Symptoms of *Fusarium* and *Verticillium* are almost identical, and can be accurately identified only through laboratory examination. These pathogens plug the xylem vessels, interfering with the translocation of water and nutrients. Symptoms include wilting, marginal necrosis, and yellowing (and, eventually, browning) of older leaves. Plants are usually stunted, and bloom production is reduced. Plants usually die, particularly from an early infection. The vascular tissue usually has a brownish or reddish-brown discolouration.
- Many weeks can pass between the initial infection and the appearance of symptoms.
- *Fusarium* can cause stem and crown rots that result in wilting and collapse. The dark-brown to black lesions develop on the stem at, or just below, the soil line, with the leading edge often pinkish or reddish. Infection occurs inward—there is usually no internal stem discolouration.
- *Fusarium* is a very common pathogen of a wide range of greenhouse crops. *Verticillium* is much less common, and usually attacks only chrysanthemum, aster, and dahlia.
- The fungal pathogens persist for long periods as thick-walled resting spores in soil or plant debris. The spores form when plant tissue begins to dry up.
- Host plant stress makes plants susceptible to a fungal wilt pathogen attack and strongly influences attack severity. Stress can include high or low air/media temperatures, or improper watering, nutrition, media pH, or EC.
- With bacterial wilt infections, wilting of entire leaves or leaf margins is the first symptom. Infections become systemic very quickly, moving through the leaf veins and petioles. Entire leaves yellow or develop large, V-shaped yellow lesions. When bacteria invade the stems, the outside of the stem usually appears gray-black and water-soaked, while the internal stem tissue appears black.
- Bacterial disease development is enhanced by high air and media temperature and by high relative humidity.
- Bacteria survive only in living or decaying plant material.
- Pathogen spread during the propagation process is very common. Both fungal and bacterial pathogens are spread by water movement through media, splashing, and the physical movement of infected media and plant material through and between operations.

Disease Control

- Use pathogen-free cuttings and seeds.
- Remove and destroy all infected plants.
- Sanitize benches, used trays, and pots.
- Thoroughly pasteurize beds for soil-grown crops.
- Maintain good horticultural practices.

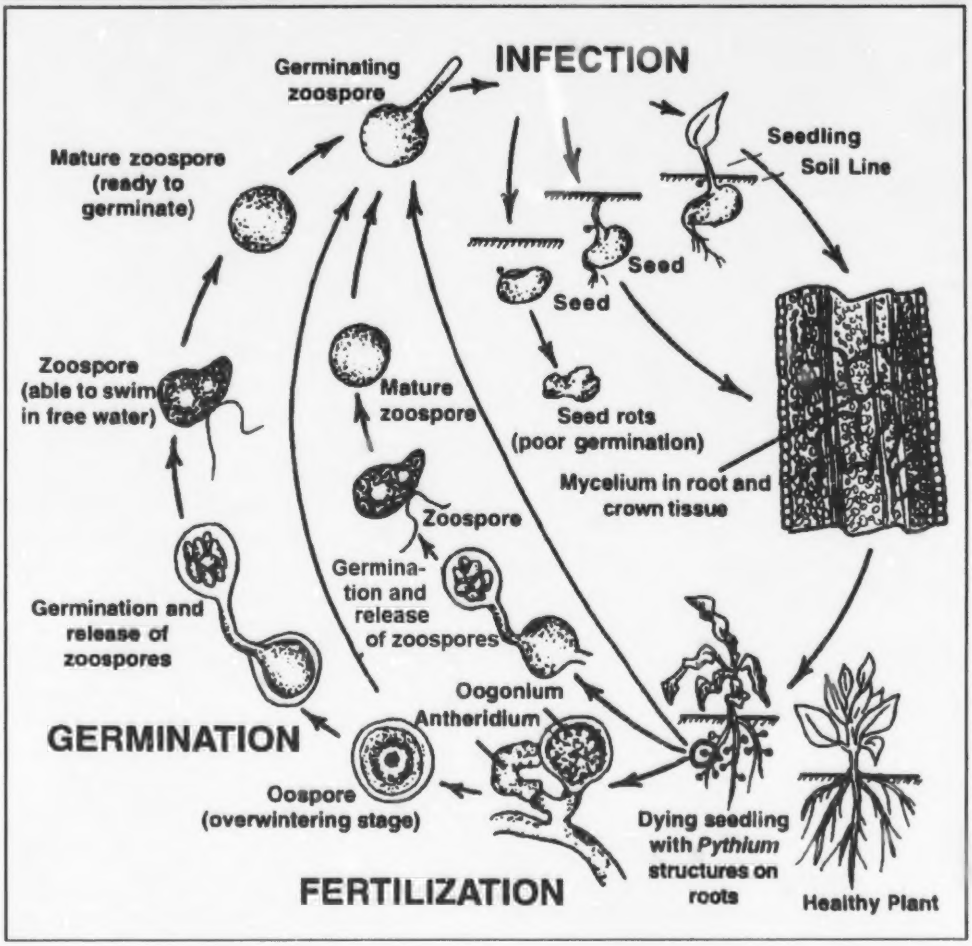
Damping-Off of Seedlings

- *Rhizoctonia solani*, *Pythium*, and *Phytophthora* are the primary causes of this disease, which attacks germinating seeds and seedlings. However *Fusarium, Botrytis, and Sclerotinia* are occasionally responsible.
- In pre-emergence damping-off, the seed dies before it germinates or before the seedling emerges from the media. Growers often misdiagnose the cause of poor emergence as poor seed quality.
- Although damping-off by *Rhizoctonia* can occur before seedlings emerge, growers usually associate it with seedling stem rot near the soil surface. This causes the seedlings to fall over. Another common association is with "wire stem," a girdling, black stem lesion that causes stunting and eventual death.
- Water moulds like *Pythium* and *Phytophthora* can attack seeds but commonly induce rot from the tips

of the young roots. This is most severe at high moisture levels.

- Wet media, poor sanitation, poor ventilation, high humidity, cool temperatures, and thick stands of seedlings are ideal conditions for damping-off fungi.

FIGURE 7–5. Damping-Off and Seed Decay Life Cycle


INFECTION
Germinating zoospore
Mature zoospore (ready to germinate)
Seedling
Soil Line
Seed
Seed
Zoospore (able to swim in free water)
Mature zoospore
Seed rots (poor germination)
Mycelium in root and crown tissue
Zoospore
Germination and release of zoospores
Germination and release of zoospores
Oogonium
Antheridium
GERMINATION
Oospore (overwintering stage)
Dying seedling with Pythium structures on roots
Healthy Plant
FERTILIZATION

Disease Control

- Sanitation is important. These pathogens can spread due to dirty seedling trays, infested media, and dirty tools. Remove all infected seedling trays.
- Splashing water will spread the organisms.
- Use only new or sanitized flats.
- Use a porous, well-drained seedling mix.
- Maintain proper temperatures throughout the various phases of seedling germination and growing on.
- Don't contaminate media used for seeding with dust or used media.
- Reduce misting as soon as possible after seedling emergence.

Crown and Root Rots

The fungi that most commonly cause crown and root rots are, in order of importance, *Pythium*, *Rhizoctonia*, *Phytophthora*, *Fusarium*, *Thielaviopsis*, and *Sclerotinia.*

- Crown and root rot fungi are soil-inhabiting pathogens. These rots constantly threaten the commercial greenhouse grower. Note that each of these disease-causing fungi has unique environmental needs.
- "Root rot" is a general term for the rotting of roots by various fungi. Root rot begins when the cortical roots become dysfunctional. They appear water-soaked and have a brown to black discolouration. New root development is reduced. As the rot

progresses, the leaves become yellow and stunted; eventually they wilt.

- Root rots debilitate individual plants and groups of plants. They compromise crop uniformity and often cause symptoms of nutritional imbalance.
- Root pathogens are more difficult to diagnose visually than many foliar diseases.

Disease Control

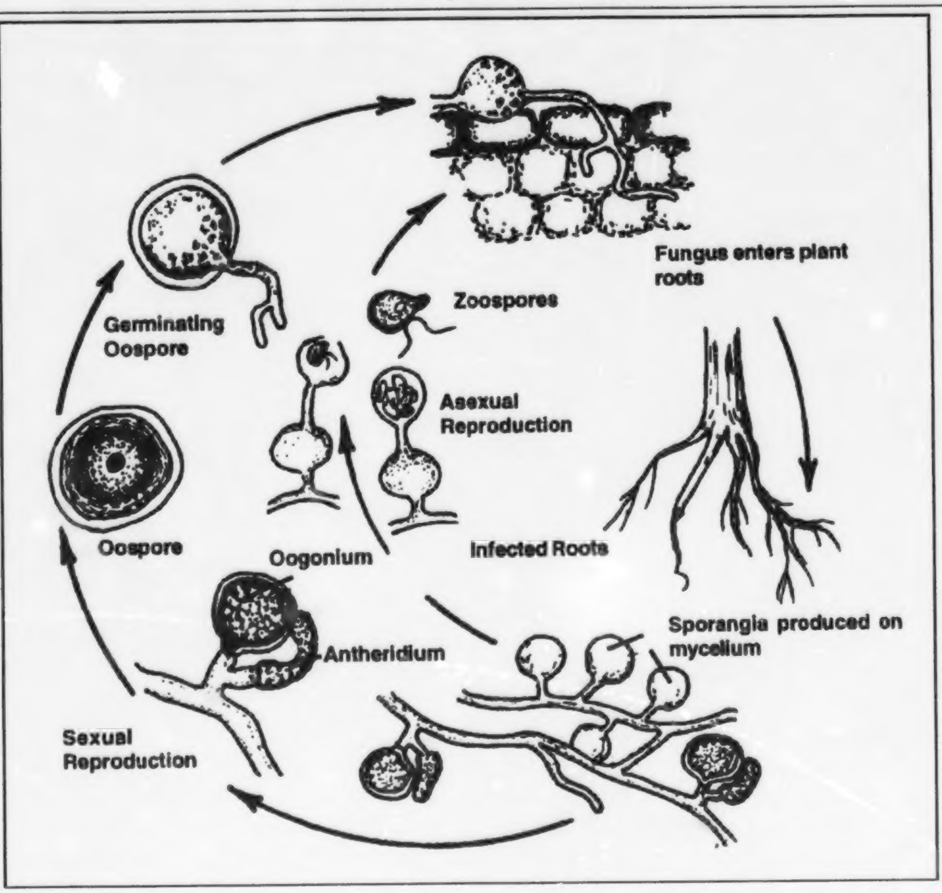
- All fungal root rot pathogens can survive in growing media or on infested tissues as mycelium or spores. They can also exist as oospores (*chlamydospores, sclerotiaresting*), resting structures in the soil that remain viable for long time periods. When they contact roots of a susceptible host, they become active (germinate) and begin infecting root tissues. Completely eliminating the inoculum source is difficult, so preventing their activity is the key to control.
- All root rot fungi can be spread by splashing water and irrigation water. Fungi can also be carried over in contaminated media, soil under benches, infested plant residues, dirty containers, blowing dust, capillary mats, and irrigation water.
- Healthy plants resist root rot infection.
- Crop stress is the leading environmental cause of crown and root rots, predisposing plants to attack. Factors contributing to crop stress include fertility level, EC, media pH, watering practices, temperature, light level, and pesticide and growth-retardant application. Each root pathogen has a different optimum temperature, pH, and moisture requirement.
- Irrigation water from storage ponds collected from runoff may contain root rot pathogens.
- Most artificial media are considered pathogen-free, and have few naturally occurring fungi or bacteria that can act as suppressive agents.

Pythium

Pythium is the most common greenhouse root rot pathogen. It causes the roots and crowns of many plants to rot.

- Symptoms vary with the age and development stage of the affected plant. Older-plant infections are usually limited to roots and root hairs. Infected roots are often soft, mushy, and various shades of brown.
- The rot begins as water-soaked brown rot of the root tips and cortex. Usually the cortex sloughs off, leaving the vascular cylinder (which remains thread-like). Lesions can occur on crowns of more succulent crops such as gloxinia.
- Aboveground symptoms include stunting, wilting, and yellowing due to nutrient and water deficiencies.
- *Pythium* spores germinate in response to root exudates. These provide food until the white, slender, profusely branching, and rapidly growing mycelium penetrate the roots.
- *Pythium* quickly produces two types of spores:
  - Asexual zoospores, which, when released, can swim in films of water until contacting healthy host tissue. There they geminate and start a new infection
  - Sexual oospores, which are thick-walled and resist both high and low temperatures.

FIGURE 7–6. Pythium Life Cycle


Fungus enters plant roots
Zoospores
Germinating Oospore
Asexual Reproduction
Oospore
Oogonium
Infected Roots
Sporangia produced on mycelium
Antheridium
Sexual Reproduction

Disease Control

- Pythium infections are most common at temperatures below 18°C.
- Maintain temperatures favourable for plant growth.
- Avoid overwatering when the crop is young or is not growing actively.
- Use a porous, well-drained media.
- Check regularly for high salts.
- Don't fertilize with excess nitrogen.
- Monitor fungus gnat populations. Both fungus gnat larvae and adults can spread the pathogen.
- See also the section on general root rot control strategies.

Phytophthora

Phytophthora causes root and crown rots similar to *Pythium* but occurs most often during the summer growing period.

- Like *Pythium,* it is a water mould—the asexual spores and mycelium spread quickly in films of water.
- Typical symptoms include necrotic brown to black lesions on larger roots and many small dead roots. Basal cankers with black streaking often appear.

Disease Control

- Avoid overwatering when the crop is young or is not growing actively.
- Use a porous, well-drained media.
- Avoid media temperatures above 26° C.
- See also the section on general root rot control strategies.

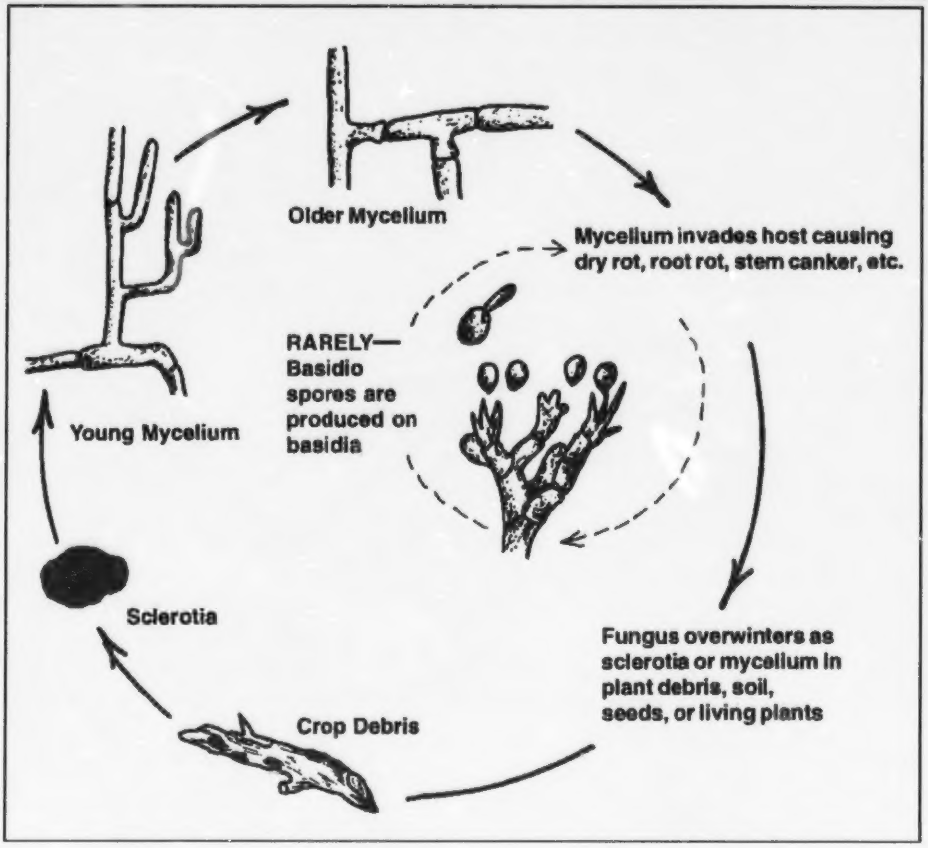
Rhizoctonia

Rhizoctonia is commonly associated with damping off but can also occur in rooted cuttings and well-established plants.

- The symptoms vary with the host and development stage but generally cause reddish-brown lesions on the belowground stem and roots of infected plants. Under favourable conditions, the lesions increase in

size and number to include the whole base of the plant.
- This pathogen is slow to girdle the crown and root area of established plants. As a result, the grower may not observe plants wilting or appearing stunted until long after the initial infection.
- Lower leaves of infected plants usually yellow, and plants may break off at the soil line.
- On fleshy, succulent stems, bulbs, and corms, the brown or black sunken lesions are often dry.
- Stem cankers can occur on lower branches where infested media have been splashed.

FIGURE 7–7. Rhizoctonia Life Cycle


Older Mycelium
Mycelium invades host causing dry rot, root rot, stem canker, etc.
RARELY—Basidio spores are produced on basidia
Young Mycelium
Sclerotia
Fungus overwinters as sclerotia or mycelium in plant debris, soil, seeds, or living plants
Crop Debris

Disease Control

- High media and air temperatures and high relative humidity promote *Rhizoctonia* in most greenhouse crops.
- Wet/dry extremes in the growing media will enhance *Rhizoctonia* development.

Thielaviopsis basicola

Thielaviopsis basicola causes a severe, black root rot of several major greenhouse flower crops. These include cyclamen, fuchsia, geranium, kalanchoe, primula, petunia, pansy, and poinsettia.

- Infected roots usually have black lesions covering all or part of the root.
- Plants usually appear stunted, with yellow or white leaves typical of a severe nutritional deficiency. The roots die rapidly, causing plant death.

Disease Control

- *Thielaviopsis* thrives with high media moisture and a high pH.
- Avoid temperatures too high or too low for the crop.
- Avoid high ammonium nitrogen fertilization, which promotes a *Thielaviopsis* attack.
- Maintain good sanitation.
- *Thielaviopsis* is hard to eradicate when growing on wooden benches or from the ground. Fortunately, this disease is not common.

Fusarium

Several *Fusarium* species cause stems, crowns, corms, bulbs, and tubers to rot. The primary culprits are *F. solani* and *F. oxysporum*.

- With root rots, the infected tissue is usually dark red to brown and may appear as streaks up to the soil line. Plant growth is usually retarded. As infection increases, the oldest leaves begin to yellow, and younger leaves become flaccid.
- In stem rots affecting plants such as chrysanthemum and carnation, the infected plants wilt and die from a stem rot at the base of the plant.
- The lesions that develop at or just below the soil line often have pink or red edges leading to the infections. The lesions develop inward. There is usually no internal stem discolouration.
- Bulb and corm rots can occur in the field and in storage. The rot usually begins at a wound or at the base of these organs and may not produce visible symptoms. However, the basal plate and fleshy scales will be brown and decaying, with mats of mycelium. The foliage often turns purple or yellow and dies prematurely.

Disease Control

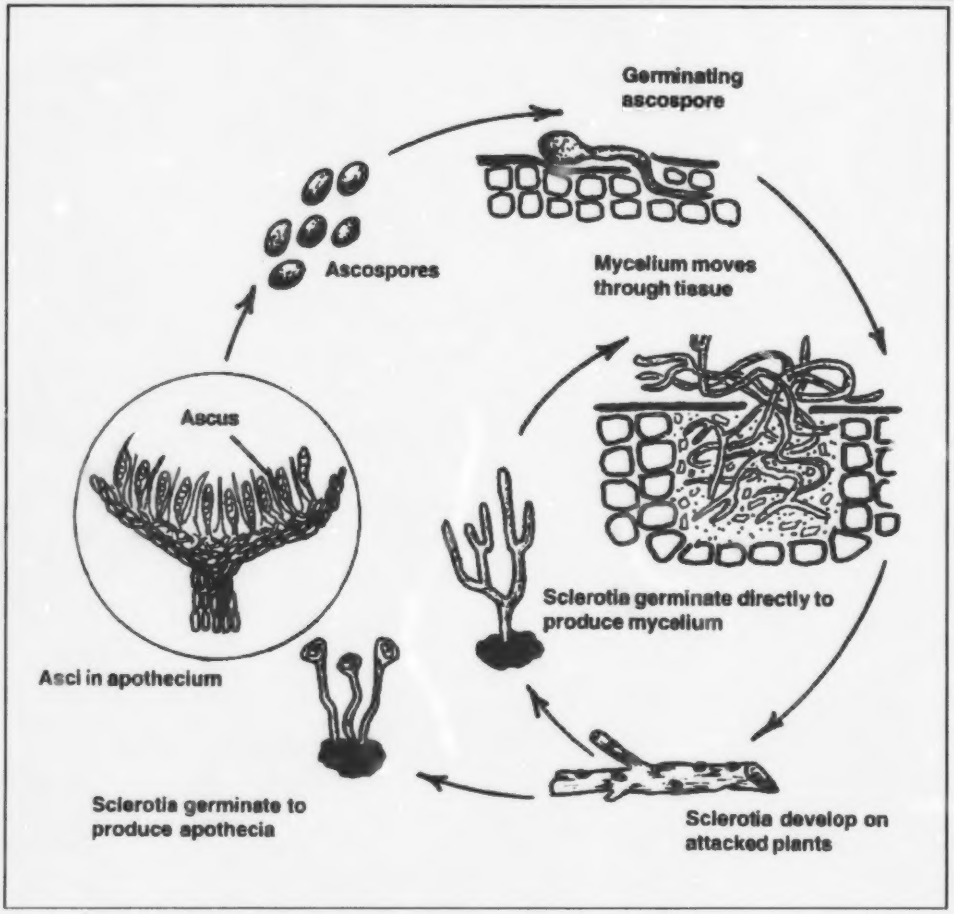
- Crop stress is the leading environmental cause of *Fusarium*, predisposing plants to attack. Standard disease control strategies apply. Review your production practices and modify them as needed to minimize crop stress.
- Maintain proper temperatures, avoiding hot and cold extremes.
- Irrigate consistently. Wet/dry extremes enhance *Fusarium* development.
- Use appropriate media.
- Pasteurize the soil for effective control in soil-grown crops.
- Use healthy, disease-free stock for vegetative propagation purposes.

Sclerotinia

Sclerotinia attacks many herbaceous ornamental and vegetable crops, including chrysanthemum, snapdragon, salvia, dahlia, delphinium, tomato, pepper, and eggplant.

- Symptoms vary with the host, the affected host part, and the environmental conditions. The most obvious early symptom is fluffy, thick, white mycelium on the stems of plants near the soil surface. Relatively large, hard, charcoal-black, resting fruiting structures (called "sclerotia") soon appear. These are embedded in the mycelium or in the pith of plant stems.
- The fungus causes a stem rot, which eventually leads to wilting and then kills the plant.
- During the early infection stages, no visible signs of infection appear on the foliage until the fungus grows completely through the stem. The exception is when the initial infection occurred through a leaf.
- *Sclerotinia* fungus survives either as sclerotia in plant tissue, in the soil for at least three years, or as mycelium in dead or living plant material.

FIGURE 7–8. Sclerotinia Life Cycle


Germinating ascospore
Ascospores
Mycelium moves through tissue
Ascus
Sclerotia germinate directly to produce mycelium
Asci in apothecium
Sclerotia germinate to produce apothecia
Sclerotia develop on attacked plants

Disease Control

- Pasteurize the soil for effective control in soil-grown crops.
- For bench-grown crops, control can be difficult. Maintain dry foliage by minimizing overhead watering and dripping and provide good air circulation through the crop canopy.
- This disease is most problematic in spring and summer.

Rusts

The rust fungi of greenhouse crops are "microcyclic." They are host-specific and do not require an alternative host to complete their life cycle. Rust may occur on carnation, chrysanthemum, fuchsia, geranium, snapdragon, and many outdoor perennials.

- Rust diseases produce masses of white, yellow, orange, or brown to reddish-brown uredospores on the undersurface of leaves and stems. These appear when the pustules erupt to release the mature spores. First symptoms usually appear within 5–7 days of infection, depending on environmental conditions.
- The various rusts can produce concentric ring patterns. These rings are due to environmental conditions conducive to secondary and tertiary infections. The leaf surface directly above the pustule is usually yellow. Numerous infection sites on a leaf will cause yellowing, and eventually senescence, of the leaf. The lower leaves are usually infected first. Plants are rarely killed.
- Rust spores spread via air currents and by splashing water within a greenhouse. Spores can travel long distances on the leaf surfaces of cuttings. A film of water must remain on upper leaf surfaces for at least 3–4 hours for spore germination and infection. However, sporulation is on the undersurface.

Disease Control

Chrysanthemum white rust is the only quarantinable rust disease of greenhouse ornamentals. Chrysanthemum white rust appears as creamy-coloured pustules on the undersurface of the lower leaves.

Growers receiving imported stock they suspect is infected should contact the Canadian Food Inspection Agency.

- Controlling rust diseases is difficult. Most produce more than one type of spore, and infected plant residue (e.g., under benches) can harbour the spores for long periods.
- A temperature range of 10°C –25°C favours spore production.
- Spores are released into the air more readily with diurnal relative-humidity fluctuation.
- Infections are often severe near fans and in corners of the greenhouse.
- Severe infections also occur under conditions of poor air circulation and temperature stratification due to crowding or a heavy canopy.
- Avoid overhead watering or late-afternoon watering.
- Prevent dew formation on plants by providing adequate heating, ventilation, and air circulation at night to control relative humidity around and through the plant canopy.
- Remove as many infected leaves as possible to reduce the inoculum level.

Pre-Emergence Damping-Off

Pre-emergence damping-off kills seeds before germination, or soon after. The young plants never emerge from the soil. Growers often mistakenly blame this loss on poor seed.

Post-Emergence Damping-Off

Most growers are familiar with post-emergence damping-off. The stem is invaded near the soil surface. The seedling wilts, the stem collapses, and the plant topples over. Other variations of post-emergence damping-off include top rot or top damping-off, and root rot.

Wire-Stem Damping-Off

In wire-stem damping-off, seedlings that have been hardened off are attacked by damping-off organisms. Stems are partially girdled, discoloured, and wire-like in appearance, hence the name wire stem. Infected plants are stunted and eventually die.

Bacterial Diseases

Bacteria are single-celled organisms that multiply rapidly under ideal temperature conditions. Their rate of development and spread increase with temperature, moisture availability, and food supply.

- Some plant pathogenic bacteria attack only one or two plant species; others attack a wide range of plants. Plants commonly attacked by bacteria include geranium, begonia, chrysanthemum, calla lily, and hibiscus.
- Bacterial infections may appear as wilts, stem and root rots, leaf spots, galls, and fasciation of plant parts. Although bacterial diseases are less common than fungal diseases, they can be very destructive and difficult to control. *Erwinia, Pseudomonas,* and *Xanthomonas* are the most common disease-causing bacteria affecting greenhouse crops. The bacteria can live on or in roots, leaves, and stems of hosts, and in non-host plants.
- Bacteria do not produce spores. Most bacteria survive in the greenhouse in a semi-dehydrated state, infecting plant debris for extended periods of time.
- Bacteria enter wound sites and natural plant openings such as stomates and hydathodes. A film of water is usually required for a bacterial infection to begin on aboveground plant parts.

Disease Control

- No chemical controls will eradicate bacterial diseases. Prevention is the key.
- Good cultural practices and careful sterilization procedures reduce the chance of bacterial infection.
- Purchase disease-free stock from the plant breeder for propagation purposes.
- Isolate stock plants in a thoroughly disinfected area.
- Disinfect cutting tools and propagation areas frequently.
- In general, warm temperatures are required for bacteria to develop rapidly.
- Bacteria spread on leaves and stems by condensation, splashing water, and during pruning or harvesting of cuttings.
- The disease can spread very rapidly on propagation benches.
- Both fixed and organic copper sprays are reasonable protectants against bacterial diseases. However, they are not eradicants and may cause phytotoxicity.

Erwinia carotovora

Erwinia carotovora causes soft-rot symptoms that first appear to be just water-soaked but quickly break down into a foul-smelling, mushy rot. This disease thrives in warm, humid conditions.

Erwinia chrysanthemumi

Erwinia chrysanthemumi attacks a wide range of floral crops including foliage, chrysanthemum, poinsettia, and begonia. Its symptoms include root rots, leaf blights, and wilts.

Xanthomonas campestris

Xanthomonas campestris and its various strains cause leaf spots and stem rots on a wide range of plants. These include begonia, geranium, zinnia, and dieffenbachia. Symptoms range from small, well-defined spots with yellow margins on the leaves to systemic activity where leaf veins become gray-green.

- Infected leaves wilt and eventually turn yellow and die. Stems turn dark green as the vascular tissue becomes blocked by the bacteria. In geranium and begonia, distinctive yellow V-shaped areas bounded by major veins usually appear in many leaves.
- Some hosts show no clear symptoms, but may appear not very vigorous.
- *Xanthomonas* is very destructive in geranium. It infects all cultivars of zonal, ivy , seed, and Martha Washington types. It is a systemic disease that can quickly kill a geranium.

Viral Diseases

Viruses are disease-causing agents that multiply only within living plant cells. They tend to spread throughout the host plant through the vascular system. The important horticultural crops belong to major plant families that are susceptible to viral attack.

- Viruses can be spread by sucking insects, such as aphids and leafhoppers, by tools, or by crop handling such as plant cleaning, disbudding, or taking cuttings. Some viruses spread via infected cuttings.
- The first viral infection symptoms may include vein banding, flecking, ring spots, mosaic (irregular areas of dark and light green on the leaf), or growth abnormalities in the leaves. The specific symptoms depend on the type of virus. Symptoms do not always increase in severity. Some viruses cause stunting. In severely infected plants, the growing point of the plant may die.
- The extent of the visible symptoms depends on the duration of the infection, the age of the plant at the time of infection, and the growing conditions for the crop.

Disease Control

- No chemical controls will eradicate viral diseases. Prevention is the key.
- Good cultural practices and careful sterilization procedures reduce the chance of viral infection.
- Purchase disease-free stock from the plant breeder for propagation purposes.
- Isolate stock plants in a thoroughly disinfected area.
- Disinfect cutting tools and propagation areas frequently.
- Crop stress predisposes plants to a virus attack. Symptoms will be more apparent in stressed plants.

Tomato Spotted Wilt Virus/Impatiens Necrotic Spot Virus

Tomato spotted wilt virus (TSWV) and impatiens necrotic spot virus (INSV) are very unusual among plant viruses. They are complex particles spread by a few thrips species, and they have a broad host range. INSV is the most common; TSWV usually affects only chrysanthemum.

- In Ontario greenhouse production, TSWV and INSV are transmitted only by western flower thrips. Unlike other insect vectors, thrips must feed on infected plant tissue as first instar larvae to acquire the virus. Virus transmission occurs when infective adults feed and continues for as long as the thrips are alive.
- Characteristic symptoms vary depending on the host species and age. For many hosts, large brown or black circular ring spots appear on the foliage. In some hosts the virus becomes systemic, with black streaking of the major leaf veins, petioles, and (in some plants) the stem.
  - In cyclamen, 8–10 weeks may pass between transmission and the first symptoms. Symptoms generally appear more quickly when plants are growing vigorously.
  - When young gloxinias are infected, the virus rapidly develops systemically. Symptoms appear similar to *Phytophthora* crown rot.
  - In other crops, such as petunia, the viral symptoms appear as small, discrete, tan-coloured spots.
  - Sometimes the symptoms mimic pesticide phytotoxicity.

Disease Control

- A simultaneous, multi-prong approach is necessary for successful control.
- It is very difficult to control the virus during warm weather.
- Rogue virus-infected plants, stock plants, and finishing plants to prevent first instar larvae from acquiring the virus.
- Control thrips populations to prevent viral spread. See the section on thrips for information on control measures.
- Purchase only clean cuttings from reputable propagators.
- Isolate stock plants in a thrips-free area.
- Screening of vents is beneficial.
- Weed control is important—many weeds are reservoirs of the virus.

8. Chemical Activity and Toxicity—Flower Crops

***The relative toxicity of a pesticide may be referred to as its LD50. This is the amount of the active ingredient (a.i.) of the chemical in milligrams used per kilogram of test animal (usually female rats) that kills 50% of the test animals. This is commonly measured as the acute oral LD50 (above), which refers to the chemical ingested through the mouth or nose. Dermal LD50 figures, or skin penetration, are also available. The higher the LD50 figure, the less toxic the product is to humans.**

Note: Many pesticides of low acute toxicity cause long-term effects in laboratory animals. Users are therefore warned that these could be detrimental to health. Exposure should be reduced to a minimum by wearing protective clothing. Gloves, goggles, and long-sleeved shirts are particularly effective.

Inclusion of a product in these tables does not necessarily imply registration for greenhouse use or registration for a specific crop. Please read every product label!

TABLE 8–1. Fungicidal Activity—Flower Crops

	Disease									
Fungicide	***Botrytis***	***Fusarium***	**Leaf Spot[1]**	**Powdery Mildew**	**Rusts[2]**	***Pythium***	***Phytophthora***	***Rhizoctonia***	***Sclerotinia***	***Thielaviopsis***
Aliette						X	X			
Benlate	R	R	X	R				X	X	X
Botran	X									
Captan	X		X			R				
Daconil 2787	X	X	X	X	X			X		
Decree	X									
Easout	R	R	X	R				X	X	X
Exotherm Termil	X									
Ferbam			X		X					
Meltatox				X						
No Damp								X		
Nova				X	X					
Quintozene								X	X	
Rovral	X							X	X	
Subdue						X	X			
Sulfur			X	X						
Truban						X	X			
Maneb			X		R					

[1] Check label for specific leaf spot control.

[2] Carnation rust only.

R = possible resistance

X = effective disease control

TABLE 8–2. Insecticide Toxicity—Flower Crops

Insecticides and Miticides

Common Name	Trade Name	LD50 (mg a.i./kg)*	Chemical Family	Ontario Schedule Number
Avermectin	Avid	300	Avermectin	3
Acephate	Orthene	866	Organophosphate	2
Bacillus thuringiensis	Dipel, Thuricide, Vectobac	15,000+	Biological	3
Bendiocarb	Trumpet	179	Carbamate	2
Carbaryl	Sevin	560	Carbamate	3
Chlorpyrifos	Lorsban, Dursban	135	Organophosphate	3
Cyromazine	Citation	3,387	Triazine	2
Deltamethrin	Decis	535	Synthetic Pyrethroid	2
Diazinon	Diazinon, DZN 600EW	300	Organophosphate	2
Dichlorvos	DDVP Smoke (Sanex Vapo)	80	Organophosphate	3
Dicofol	Kelthane	684	Organochlorine	2
Dienochlor	Pentac	3,160	Organochlorine	3
Diflubenzuron	Dimilin	4,640	Substituted Benzoylurea	2
Pyridaben	Dyno-Mite	1,930	Pyridazinone	2
Endosulfan	Thiodan	110	Organochlorine	2
Fenbutatin oxide	Vendex	2,631	Organotin	3
Imidacloprid	Impower	1,858	Chloronicotinyl	5
Kinoprene-S	Enstar	4,900	I.G.R.	3
Lindane	Lindane	88	Organochlorine	2
Malathion	Malathion	1,400	Organophosphate	3
Naled	Dibrom	430	Organophosphate	2
Nicotine	Nicotine Smoke	50	Botanical	2
Oxydemeton-methyl	Metasystox-R	75	Organophosphate	2
Parathion	Parathion Smoke	3.6	Organophosphate	5
Permethrin	Ambush, Pounce	4,000+	Synthetic Pyrethroid	3
Pirimicarb	Pirimor	147	Carbamate	2
Sulfotep	Sulfotep 103 Smoke	10	Organophosphate	5

TABLE 8–3. Fungicide Toxicity—Flower Crops

Fungicides				
Common Name	**Trade Name**	**LD50 (mg a.i./kg)**	**Chemical Family**	**Ontario Schedule Number**
Benomyl	Benlate	10,000+	Benzimidazole	3
Bromine	Agribrom	1,390		3
Captan	Captan	9,000	Phthalimide	2
Chlorothalonil	Exotherm Termil, Daconil 2787	10,000+	Aromatic hydrocarbon	
Copper	Phyton-27	5,000+	Copper	3
Dazomet	Basamid, Mylone	519	Diazine	3
Dichloran	Botran	10,000+	Dicarboximide	3
Dodemorphacetate	Meltatox	4,180	Morphactin	3
Etridiazole	Truban	1,077	Thiadiazole	3
Fenhexamid	Decree	5,000+	Hydroxy.	2
Fixed Copper	Fixed Copper, Tricop, Basicop, Kocide 101		Inorganic	
Folpet	Folpan	10,000+	Phthalimide	2
Fosetyl-Al	Aliette	5,000	Phosph.	2
Iprodione	Rovral	3,500	Dicarboximide	3
Oxine benzoate	No-Damp	1,000+	Aromatic hydrocarbon	3
Mancozeb	Manzate 200	6,750	Dithio carbamate	
Metalaxyl	Subdue 2G	669	Acylalanine	2
Myclobutanil	Nova	1,870	Triazole	2
Quintozene	Quintozene	30,000	Aromatic hydrocarbon	3

TABLE 8–4. Growth Regulator Toxicity—Flower Crops

Growth Regulator				
Common Name	**Trade Name**	**LD50 (mg a.i./kg)**	**Chemical Family**	**Ontario Schedule Number**
Ancymidol	A-Rest	40	Pyrimidine	6
Chlormequat	Cycocel	478	Quaternary Ammonium	2
Daminozide	B-Nine	6810	Organic Acid	2
Paclobutrazol	Bonzi	5000+	Triazole	2
Uniconazole	Sumagic	1790	Triazole	2

9. Using Plant Growth Regulators for Flower Crops

Plant growth, especially vegetative growth, can be controlled by a number of cultural and environmental management techniques. These include:

- growing a crop under moisture stress, which can be accomplished by withholding water within the growing substrate as well as maintaining very low relative humidity.
- nutrition, particularly excess nitrogen fertilization, which increases cell expansion and ultimately stem elongation.
- maintaining a lower day than night temperature (negative DIF) or by providing a sudden temperature drop during the morning hours beginning with the first light. In addition, raising or lowering the average 24-hour temperature will increase or retard the rate of plant growth.
- providing high light intensities in the greenhouse.
- removing end-of-the-day twilight from the greenhouse by using blackout or shade cloth, which increases the red/far-red light ratio. (Far-red light has been shown to be an important factor in the stem elongation of plants).
- mechanical stress. Growing the plants in an environment with strong air movement or brushing the plants a number of times per day will reduce plant height.
- plant growth regulators. Growth regulators have become an important cultural tool in modifying plant development in greenhouse flower crop production during the last three decades. They influence different plant processes, such as stem elongation, branching, rooting, flower induction, and vegetative growth. This section concentrates on factors to consider in limiting vegetative growth (controlling height).

Factors to Consider

Plant Vigour

Plant growth regulators (PGRs) should be provided only to vigorously growing plants or to vigorous cultivars. Weaker plants or less vigorous cultivars should be avoided, as height reduction may be excessive. Growth regulators impose a stress on plants, and healthy, vigorous plants are more likely to tolerate this stress. A dehydrated plant is more susceptible to phytotoxicity from a PGR than is a turgid plant. Apply growth regulators only to plants with well-established root systems. For example, A-Rest applied to Easter lilies with poor root development can cause undue loss of bottom leaves.

Cultivar Response

The growth habit of a cultivar determines the growth regulator concentration and the number of applications required. For example, a tall-growing pot mum such as the Princess Anne series will generally need a higher concentration of growth retardants than shorter cultivars such as Mandalays. The same is true for certain poinsettia lines.

Environment

Plants grown under low temperature and light may require fewer growth-regulator applications than those grown under higher light and temperatures. Adjust concentrations accordingly for winter and summer production. Do not apply growth regulators when temperatures exceed 22°C. If possible, apply them during the evening or during periods of low transpiration losses so that the PGR can be absorbed by the plant tissue. This is particularly true for contact PGRs such as B-9 and, to a lesser extent, Cycocel. Bonzi and Sumagic, both systemic PGRs, are quickly absorbed within the plant tissue.

Stage of Plant Growth

Growth regulators are most effective when applied to young, vigorous plants. A-Rest applied to Easter lilies under 10 cm high may reduce bud count, delay flowering, or severely stunt plant growth. However, when applied too late, A-Rest or Sumagic will produce lilies with a palm tree effect; or, on poinsettias, bracts that are too small. Early application may affect the development of some (bottom) breaks on poinsettia and chrysanthemum. This is most pronounced with high rates and the more effective growth regulators.

Much lower rates of Bonzi or Sumagic must be applied to bedding plant plug seedlings than when applying to established plants in cell packs or baskets.

Dosage and Coverage

For most PGRs, the concentration of the active ingredient (a.i.) in the solution to be applied is critical. For simple conversion on a normalized level (1 or 1000 ppm a.i.) see table below. You must measure accurately using proper weighing instruments and/or measuring containers. For A-Rest, the recommendation is for drenching and is expressed as total active ingredient (a.i.) per pot. This means that the solution concentration (mg/L or ppm) multiplied by the solution volume to be applied (L/pot) should equal the dosage (mg/pot).

TABLE 9–1. Dilution Guidelines for Plant Growth Regulators

Product Name	Active Ingredient	Formulation	Spray or Drench Solution 1 ppm	 1000 ppm
A-Rest	Ancymidol	0.0264% (0.264g/L)	3.8mL/L	
B-9	Daminozide	85 SP (850g/kg)		1.2 g/L
Bonzi	Paclobutrazol	0.4% (4g/L)	0.25mL/L	
Cycocel	Chlormequat	11.8% (118g/L)		8.5 ml/L
Sumagic	Uniconazole	0.055% (0.55g/L)	1.8 ml/L	

- Always read the label. There may be different formulations on the market, or the formulation may have changed. Use the material according to the manufacturer's directions. The label may also indicate the need for a spreader sticker.
- Store growth regulators in a cool, dry, dark place. Do not allow temperatures to drop below 0°C. Shelf life is at least two years.
- Note that some growth regulators may become unstable once mixed with water. To prevent breakdown, mix just before using.

Application Methods

Drench

- Some growth regulators are systemic within the plant's vascular system (e.g., A-Rest, Bonzi, Cycocel, and Sumagic). Drenching from above may distribute the chemical more evenly within the plant, increasing control. Application of PGRs by subirrigation has not been approved as yet. Concerns are with rates and the residues remaining on the tables, floors, or troughs.
- Drench treatment is more precise than spraying but generally requires more labour.
- Be sure roots are well developed before applying the chemical. ***This is critical for an A-Rest drench on Easter lily.***
- Be sure plants are not stressed. Injury can occur if plants are even a little dry. It may be wise to water the plants in late afternoon and apply the treatment the following morning. Another reason for watering the day before is to have a more-even distribution of the PGR throughout the substrate in the pot.
- Apply adequate amounts of solution to wet the entire root mass.
- Drench applications of Sumagic and Bonzi are extremely effective. Accuracy is critical.
- Pine bark–based mixes will reduce the efficacy of A-Rest, Bonzi, and Sumagic.

TABLE 9–2. Recommended Drench Volume

Pot diameter(cm)	Volume of solution (mL/pot) Drench	 Spray
10	90	3
13	120	6
15	180	10
20	240	17.5
25	300	25

Spray

- Spray application is easier than using a drench, but ensuring uniform foliage coverage is critical. Spraying equipment *must* be operating properly.
- Plants should be turgid to prevent foliage damage.
- When applying Cycocel or B-Nine, keep foliage dry for 12–24 hours after spraying to prevent washing the chemicals from the leaves.
- Most chemicals contain wetting agents. However, you may need a spreader to distribute the chemical uniformly on the foliage and to lessen the likelihood of leaf damage. A rate of 10–20 L of spray/100 m^2 will generally give good coverage. For young and small plants, an even smaller volume can be used.

- To prevent chemical wastage, arrange the plants as closely together as possible without undue crowding.
- Keep a separate sprayer for this job. Clean the sprayer after each application to prevent unnecessary damage from other chemical residues.
- The recommended spray volume in the Table above may be used as a guide for the volume to be applied.

PGRs when applied as foliar sprays must be absorbed and transported within the plant. The active ingredient must move through the waxy cuticle layer of the leaf or stem and then into the plant tissue. Highly water-soluble PGRs such as B-Nine and Cycocel move slowly through the cuticle, while less-soluble PGRs (Sumagic, Bonzi, A-Rest) penetrate very rapidly.

For Cycocel and B-Nine, absorption occurs while the foliage remains wet, which explains why they must be applied in the early morning, at the end of the day or under cloudy, humid conditions with lower air movement. For these products, avoid overhead watering for 12–24 hours, so that the active ingredient is not washed off the plant.

A-Rest, Sumagic, and Bonzi are absorbed very rapidly (within minutes), with little potential for being washed off after drying.

Number of Applications

While a single drench or spray application is the most economical, a "one-shot" treatment is vulnerable to mistakes. A split application using the lowest recommended rate (usually half of the highest recommended rate) applied twice is a safer alternative. A 1–2 week interval between applications increases flexibility and reduces the chance of plant damage. It also allows time to monitor plant growth, take weather changes into account, and make repeated applications accordingly. Plant shape generally improves with the technique of multiple applications.

Estimating Final Plant Height

Floriculture researchers have found that the final height of chrysanthemum, Easter lily, and poinsettia can be predicted using growth charts over time (graphical tracking). Graphical tracking can help determine the effectiveness of a growth retardant and the need for additional applications. Four weeks following the start of short days, chrysanthemum and poinsettia reach approximately half their final height at maturity. Easter lilies will approximately double in height from the time of visible bud. By measuring the plant height from the pot rim at this time and doubling this number, you get an estimate of the final height. If the 4-week estimated height is too tall, an additional growth regulator may be warranted. This will reduce growth further, producing a more desirable plant. Give this system a try. If it works in your growing operation, use it in your integrated cultural program as a growth-monitoring technique. Graphical tracking programs are commercially available with typical growth curves for these crops.

Directions for Mixing Chemicals

- Always read the label. Handle the chemicals according to the manufacturer's recommendations and observe all restrictions and precautions.
- When mixing chemicals, note that the final volume of a growth regulator mixture should include the growth regulator that will be added. First measure the chemical, then add water until you reach the desired final volume of the solution.
- For example, if the label directions read 60 mL B-9/L, first add 60 mL of B-9 to a suitable measuring container, then add water to the 1 L mark. Do not add 60 mL B-9 to 1 L of water. Remember that the final solution, including B-9, should be 1 L.
- Don't add wetting agent (spreader) if the label states that this is already present in the solution. If excessive beading occurs, additional wetting agent may be added to eliminate the beading.
- Read the label to see if the material is sufficiently stable for storage after mixing. It is best to mix chemicals before each application to ensure proper chemical activity.

Don't mix growth regulators with any other pesticides. Growth-regulator applications are too critical; don't take chances to save time. Mix and apply growth regulators precisely.

Growth-Regulator Recommendations for Flower Crops

The efficacy of plant growth regulators can be very crop dependent. It is *essential* that the label is read before applying any plant growth regulator.

TABLE 9–3. Summary of Plant Growth Regulators by Crop

Crop	Registered Plant Growth Regulators
Azalea	B-Nine, Cycocel
Bedding plants	B-Nine, Bonzi, Sumagic
Chrysanthemum (pot)	B-Nine, A-Rest
Chrysanthemum (cut)	B-Nine
Geranium (seed)	Cycocel, Bonzi
Hydrangea	B-Nine
Easter lily	Sumagic, A-Rest
Lily	A-Rest
Poinsettia	B-Nine, A-Rest, Cycocel, Sumagic

TABLE 9–4. Plant Growth Regulators

A-Rest (0.0264% ancymidol)

Crops	**Chrysanthemum (potted), lily, poinsettia**
Concentration of Active Ingredient	2–8 ppm.
Mixing rate	2ppm = 7.5 mL per L water 8ppm = 30 mL per L water
Method of Application	Drench. Apply 0.25 mg active ingredient per 15-cm pot.
Timing	*Chrysanthemum*: apply just as root system spreads over outside of root ball, or approximately two weeks after pinch when laterals are 5 cm long. *Lily*: apply when lily is 7–15 cm tall. Do not apply between Jan. 23 and Feb. 7, as bud count may be reduced. Can also be used as a spray; however, bud count may be affected. *Poinsettia*: treat plants from pinch to 4 weeks after pinch; or 8–12 weeks before finish.
Comments	Entire soil must receive uniform application. Do not apply a wetting agent. Ensure healthy roots and adequate phosphorous nutrition of Easter lily to minimize lower leaf yellowing.

Cycocel (11.8% chlormequat)

Crops	**Azalea, geranium (seed), poinsettia**
Concentration of Active Ingredient	*Azalea*: 1,500–2,000 ppm *Geranium*: 2,000–3,000 ppm *Poinsettia*: 1,500–3,000 ppm
Mixing rate	2000 ppm = 17 mL per L water; 3000 ppm = 25 mL per L water.
Method of Application	Spray or drench
Timing	*Azalea*: apply twice 1 week apart after regrowth from last pinch is 2–2.5 cm long, to control elongation and improve flower initiation, or to prevent late-season growth. *Geranium (seed)*: first apply when plants have 2–4 true leaves or about three weeks after transplanting. *Poinsettia*: apply when shoots are 24 cm tall.
Comments	*Azalea*: can produce medium-hard plants, slight chlorosis, and/or uneven flowering. Also used to promote early flowering on some varieties. *Geranium (seed)*: may cause some marginal leaf burn when applied as a foliar spray. Induces earlier flowering and promotes branching. *Poinsettia*: application later than Oct. 10 may delay flower development and reduce bract size. Spraying twice with half the recommended concentration is more effective than once at the high concentration.

B-Nine SP (85% daminozide)

Crops	Azalea, bedding plants, chrysanthemum (potted and cut), hydrangea, poinsettia
Concentration of Active Ingredient	*Azalea* (2,500–3,500 ppm), *Bedding plants* (2,500–5,000 ppm); *Chrysanthemum—pots* (2,500–5000 ppm), *cuts* (2,500 ppm); *Hydrangea* (2,500–5,000 ppm), *Poinsettia* (5,000–7,000 ppm)
Mixing rate	2,500 ppm = 3.0 g/L water
Method of Application	Spray
Timing	*Azalea*: apply after last pinch when shoots are 2.5 cm long to promote development of additional buds. *Bedding plants*: apply 2–3 weeks after transplanting or when the plants begin to elongate. Repeat as required. *Chrysanthemum (pots)*: apply when shoots are 2–4 cm long. May be repeated 3 weeks later; *(cuts)*: to prevent stretching of the peduncles, spray 2 days after disbudding or 4 weeks after shade initiation. *Hydrangea*: apply first spray between 2 and 3 weeks (4–5 leaf stage); second spray one week later. *Poinsettia*: spray when shoots are approximately 5 cm tall.
Comments	*Azalea*: increases short-day response and early bud formation. Do not let solution drip onto growing medium. *Bedding plants*: good for most bedding plants but not effective on snapdragon, celosia, coleus, pansy, geranium, carnation, cleome, convolvulus, and gomphrena. *Chrysanthemum (pots)*: use low concentration on pinched crops; high concentration on single-stem plants. Spray foliage to run off; *(cuts)*: do not mix B-Nine with any other pesticides. *Hydrangea*: can apply after buds are visible if necessary. *Poinsettia*: do not add any wetting agent. Late application will delay blooming.

Bonzi (0.4% paclobutrazol)

Crops	**Bedding plants in plug trays, cell packs, or small pots.**
Concentration of Active Ingredient	0.5–60 ppm depending on method of application and crop species. ***Read the label carefully. Bonzi is extremely active at very low concentrations. It is recommended that growers test with lower concentrations on all species and cultivars.***
Mixing rate	1 ppm = 0.25 mL per L water 10 ppm = 2.5 mL per L water 50 ppm = 12.5 mL per L water
Method of Application	Spray (use 1–2L per 10 m^2 depending on the stage of plant growth) Drench (use 60–80 mL per 10-cm pot; 120–140 mL per 15-cm pot)
Timing	For bedding plants, first application should be made at the first- or second-leaf stage. Application to plants in cell packs or pots can be made once plants are established after transplanting, usually 2–3 weeks later.
Comments	Desired height control is usually obtained with a single spray or drench application, but good height control can also be obtained by repeated applications 7–10 days apart at half the recommended concentration. Care should be taken not to apply excessive amounts of spray to young plants that have not completely covered the medium; Excess may enter the medium and act as a drench, resulting in excessive stunting of sensitive species. Bonzi spray applications are absorbed through the stems, so thorough and uniform coverage is essential. Overapplication can result in stunting and delayed flowering.

Sumagic (0.055% uniconazole-P)	
Crops	**Bedding plants, chrysanthemum, Easter lily, poinsettia**
Concentration of Active Ingredient	*Bedding plants*: 1–30 ppm depending on crop species. Read the label carefully. Sumagic is *extremely active* at very low concentrations. It is recommended that growers test with lower concentrations on all cultivars. *Chrysanthemum*: 5–10 ppm *Easter lily*: 3–30 ppm *Poinsettia*: 2–8 ppm
Mixing rate	1 ppm = 1.8 mL per L water 10 ppm = 18 mL per L water 30 ppm = 54 mL per L water
Method of Application	Spray (use 1–2 L per 10 m^2 depending on the stage of plant growth) Low pressure and larger droplet size are recommended for best results.
Timing	*Bedding plants*: varies depending on the species being treated. Read the label carefully. First application is usually made when seedlings are 2.5–3.0 cm tall. *Chrysanthemum*: apply 7–14 days after pinch when the length of the breaks is 3.8–5.0 cm. A single repeat spray can be made 7–21 days after the first, to increase the level of growth reduction. *Easter lily*: apply when shoots are 7.5 cm tall. Do not make a repeat application following a spray of greater than 5 ppm. *Poinsettia*: apply when breaks are 3.5–5.0 cm long (about 10–14 days after pinching). Up to two repeat applications can be made at 7-day intervals until desired growth characteristics are achieved.
Comments	Plant response to Sumagic is strongly influenced by cultural and environmental factors such as growing media, water/fertilizer management, temperature, light, growing house composition, and other cultural practices. Treat a limited number of plants at the lowest recommended rate when using for the first time. Lower rates may be needed at lower temperatures. *Poinsettia*: Bract size and diameter may be slightly reduced with treatment, and days to flowering may be delayed if applied after the initiation of short days. *Chrysanthemum*: Two applications may have more effect than the same amount of product applied as a single treatment. *Easter lily*: Treatment with Sumagic may reduce the water requirement of Easter lily. Avoid late-season application.

10. Pest and Disease Control for Greenhouse Flower Crops

Listings in this chapter appear alphabetically by plant name. Under each plant listing, you will find a listing of pests and diseases that affect this plant.

All listed control products are registered for the listed purpose. The order in which products appear does not constitute a preference ranking.

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
African Violet (Saintpaulia)	Aphid	Impower 60 WP	Read label carefully	
		Thiodan 4 EC	1.25 L	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 50 WP	1.0 kg	
		Endosulfan 400	1.25 L	
		Endosulfan 50 W	1.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Sulfotep smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
	Cyclamen Mite	Kelthane 50 W	525–700 g	
		Thiodan 50 WP	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
	Fungus gnat	Citation 75 WP	75g/570 L	
		Dimilin 25 WP	18–150 g	
		Vectobac 600 L	2–8 L	
	Mealybug	DDVP Smoke Fumigator	1/300 m^3	
		Dibrom Insecticide	10 mL/100 m^3	
		Insecticidal Soap	20 L	
	Two-Spotted Spider Mite	Insecticidal Soap	20 L	
		Kelthane 50 W	525–700 g	
		Avid 1.9% EC	300 mL	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops or cultivars
		Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
		Rovral 50% WP	1.0 kg	
		Exotherm Termil Smoke Fumigator	1/100 m^2	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
	Crown Rot	Subdue 2 G	125–250 g/100m^2	Soil surface broadcast application
			250–1000 g/100 m^2	Soil surface incorporation at transplanting
			125 g/m^3	Soil mix at seeding and transplanting
		Truban 30% WP	175–625 g	
Aster	Powdery Mildew	Nova 40 W	340 g	
Azalea	Aphid	Impower 60 WP	Read label carefully	
		Thiodan 4 EC	1.25 L	
		Thiodan 50 WP	1.0 kg	
		Endosulfan 400	1.25 L	
		Endosulfan 50W	1.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Dibrom Insecticide	10 mL/100 m^3	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	
		Enstar II	250–400 mL	
		Insecticidal Soap	20 L	
	Cyclamen Mite	Kelthane 50 W	525–700 g	
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50W	1.0 kg	
		Endosulfan 400	1.25 L	
	Fungus gnat	Citation 75WP	75 g/570 L	
		Dimilin 25WP	18–150 g	
		Vectobac 600L	2–8 L	
	Leaf Roller	Dipel	0.63–1.25 kg	
	Thrips	Diazinon 50 EC	1.0 L	
		Diazinon 50 WP	1.0–1.5 kg	
		DZN 600EW	830 mL	
		Malathion 50 EC	2.0 L	
		DDVP Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	
			1.25 kg/ha	Soil-surface spray
	Two-Spotted Spider Mite	Kelthane 50 W	525–700 g	
		Dyno-Mite 75 W	142–284 g	
		Avid 1.9% EC	300 mL	
		Insecticidal Soap	20 L	
	Whitefly	Impower 60 WP	Read label carefully	
		Thiodan 4 EC	1.25 L	
		Thiodan 50 WP	1.0 kg	
		Endosulfan 400	1.25 L	
		Endosulfan 50 W	1.0 kg	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6L	See Pesticide Injury To Flower Crops on page 38.
		Dibrom Insecticide	10 mL/100 m^3	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
		Sulfotep Smoke Fumigator	1/300 m^3	
		Enstar II	250–400 mL	
		Pounce 384 EC	275 mL	
		Insecticidal Soap	10 L	
	Damping-Off	Truban 25 EC	300–630 mL	
	Phytophthora	Aliette WDG	2.8 kg/ha	Foliar application
Bedding Plants	Aphid	Pirliss 50 WDG	500 g	
		Impower 60 WP	Read label carefully	
		Nicotine Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 50 WP	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		DDVP Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		DDVP 20 % EC	6L	See Pesticide Injury To Flower Crops on page 38.
		Enstar II	250–400mL	Due to diversity of types, test a few plants first
		Dibrom Insecticide	10 mL/100 m^3	See Pesticide Injury To Flower Crops on page 38.
		Insecticidal Soap	20 L	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	Due to diversity of types, test a few plants first
	Fungus gnat	Citation 75WP	75 g/570 L	
		Dimilin 25WP	18–150 g	
		Vectobac 600L	2–8 L	
	Two-Spotted Spider Mite	Dyno-Mite 75 W	142–284 g	
		Kelthane 50 W	525–700 g	
		DDVP Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		Insecticidal Soap	20 L	
		Avid 1.9% EC	300 mL	
	Whitefly	Impower 60 WP	Read label carefully	
		Ambush 50 EC	200 mL	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Pounce 384 EC	275 mL	
		Dyno-Mite 75 W	284–485 g	
		Insecticidal Soap	10 L	
		Parathion Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		DDVP Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		DDVP 20% EC	6L	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 50 WP	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 4 EC	1.25 L	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		Trumpet 80 W	0.75–1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Dibrom Insecticide	10 mL/100 m^3	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops
		Exotherm Termil Smoke Fumigator	1/100 m^2	
		Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
		Rovral 50% WP	1 kg	
	Damping-Off (*Pythium/ Phytophthora*)	Truban 30% WP	250–375 g	
		Truban 25 EC	240–300 mL	
		Aliette WDG	2.8 kg/ha	Foliar application
	(*Rhizoctonia*)	No-Damp	10 L	
		Rovral 50% WP	2 g/5 L/m^2	
Begonia (Rieger)	Aphid	Impower 60 WP	Read label carefully	
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Trumpet 80 W	0.75–1.0 kg	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Vectobac 600L	2–8 L	
	Mealybug	Malathion 50% EC	2.0 L	See Pesticide Injury To Flower Crops on page 38.
		DDVP Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	
		Dibrom Insecticide	10 mL/100 m^3	
		Insecticidal Soap	20 L	
	Thrips	Diazinon 50% WP	1.0–1.5 kg	
		Diazinon 50% EC	1.0 L	
		Malathion 50% EC	2 L	
		DDVP Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	
			1.25 kg/ha	Soil surface spray
	Two-Spotted Spider Mite	Kelthane 50 W	525–700 g	
		Dyno-Mite 75 W	142–284 g	
		Vendex 50 WP	0.5–1.0 kg	
		Avid 1.9% EC	300 mL	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
		Insecticidal Soap	20–25 L	
	Whitefly	Impower 60 WP	Read label carefully	
		Ambush 50 EC	200 mL	
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		Dyno-Mite 75 W	284–425 g	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Sulfotep Smoke Fumigator	1/300 m^3	
		Pounce 384 EC	275 mL	
		Trumpet 80 W	0.75–1.0 kg	
		Insecticidal Soap	10 L	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops
		Botran 75% WP	925 g	
		Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
		Rovral 50% WP	1.0 kg	
	Root Rot (Cuttings, *Pythium/Phytophthora*)	Truban 30% WP	250–375 g	
	(*Rhizoctonia*)	Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
	Powdery Mildew	Phyton-27	1.25–2.5 L	
Bulb Crops	Tulip Bulb Aphid	Impower 60 WP	Read label carefully	
		DDVP Smoke Fumigator	1/300 m^3	
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		Dibrom Insecticide	10 mL/100 m^3	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25 WP	18–150 g	
		Vectobac	2–8L	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops
		Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro75 DF	1.5 kg	
		Daconil 2787	2.5 L	
	Blight	Daconil 2787	2.5 L	
	Crown Rot	Truban 30% WP	175–625 g	
Calceolaria	Aphid	Impower 60 WP	Read label carefully	
		DDVP Smoke Fumigator	1/300 m^3	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Insecticidal Soap	20 L	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25 WP	18–150 g	
		Vectobac 600L	2–8 L	
	Two-Spotted Spider Mite	Avid 1.9% EC	300 mL	
		Insecticidal Soap	20 L	
	Whitefly	Impower 60 WP	Read label carefully	
		Insecticidal Soap	10 L	
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Dibrom Insecticide	10 mL/100 m^3	
		Pounce 384 EC	275 mL	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops.
		Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
Carnation	Aphid	Impower 60 WP	Read label carefully	
		Diazinon 50% EC	1.0 L	
		Diazinon 50% WP	1.0–1.5 kg	
		DZN 600EW	1.25 L	
		Nicotine Smoke Fumigator	1/300 m^3	
		DDVP Smoke Fumigator	1/300 m^3	(under 20°C)
		DDVP 20% EC	6L	See Pesticide Injury to Flower Crops on page 40.
		Dibrom Insecticide	10 mL/100 m^3	
		Trumpet 80 W	0.75–1.0 kg	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25 WP	18–150 g	
		Vectobac	2–8 L	
	Thrips	Trumpet 80 W	0.75–1.0 kg	
		Diazinon 50% WP	1.0–1.5 kg	
		Diazinon 50% EC	1.0 L	
		DZN 600EW	1.25 L	
	Two-Spotted Spider Mite	Kelthane 50 W	525–700 g	
		Insecticidal Soap	20 L	
		Avid 1.9% EC	300 mL	
		DDVP Smoke Fumigator	1/300 m^3	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
		DZN 600EW	1.25 L	See Pesticide Injury To Flower Crops on page 38.
	Alternaria Leaf Spot	Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
		Daconil 2787	2.5 L	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops or cultivars.
		Exotherm Termil Smoke Fumigator	1/100 m^2	
		Daconil 2787	2.5 L	
	Leaf Spot	Daconil 2787	2.5 L	
Chrysanthemum	Aphid	Pirliss WDG	500 g	
		Impower 60 WP	Read label carefully	
		Nicotine Smoke Fumigator	1/300 m^3	
		DDVP Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Enstar II	250–400 mL	
		Trumpet 80 W	0.75–1.0 kg	
		Sultotep Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
	Caterpillar	Thuricide HPC	5 L	
		Dipel	1.0–1.25 kg	
	Cyclamen Mite	Kelthane 50 W	525–700 g	
		Thiodan 50 WP	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 4 EC	1.25 L	See Pesticide Injury To Flower Crops on page 38.
		Endosulfan 50 W	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Endosulfan 400	1.25 L	See Pesticide Injury To Flower Crops on page 38.
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25 WP	18–150 g	
		Vectobac 600 L	2–8 L	
	Leafminer	Avid 1.9% EC	600 mL	
		Citation 75 WP	75 g/400 L	
		Diazinon 50% WP	1.0–1.5 kg	
		Diazinon 50 EC	1.0 L	
		DZN 600EW	830 mL	
		Ambush 50 EC	200 mL	
	Leaftier	Diazinon 50% WP	1.0–1.5 kg	
		Diazinon 50% EC	1.0 L	
		DZN 600EW	830 mL	
	Tarnished Plant Bug	Malathion 50% EC	1.88 L	
	Thrips	Decis 5.0 EC	0.35–0.5 L	
		Trumpet 80 W	0.75–1.0 kg	
			1.25 kg/ha	Soil surface spray

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
		Diazinon 50% WP	1.0–1.5 kg	
		Diazinon 50 EC	1.0 L	
		DZN 600 EW	830 mL	
	Two-Spotted Spider Mite	Kelthane 50 W	525–700 g	
		Avid 1.9% EC	300 mL	
		Insecticidal Soap	20 L	
		Dyno-Mite 75 W	142–284 g	
		Dibrom Insecticide	10 mL/100 m^3	See Pesticide Injury To Flower Crops on page 38.
		DZN 600EW	830 mL	
	Whitefly	Enstar II	250–400 mL	
		Dyno-Mite 75 W	284–425 g	
		Impower 60 WP	Read label carefully	
		Insecticidal Soap	10 L	
		Sulfotep Smoke Fumigator	1/300 m^3	
		DDVP Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Dibrom Insecticide	10 mL/100 m^3	See Pesticide Injury To Flower Crops on page 38.
		Ambush 50 EC	200 mL	
		Pounce 384 EC	275 mL	
	Leaf Spot	Daconil 2787	2.5 L	
		Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
	Ascochyta Ray Blight	Daconil 2787	2.5 L	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops.
		Exotherm Termil Smoke Fumigator	1/100 m^2	
		Daconil 2787	2.5 L	
		Botran 75% WP	925 g	
		Rovral 50% WP	1.0 kg	
	Root Rot (*Pythium/ Phytophthora*)	Truban 30% WP	250–375 g	
		Truban 25 EC	240–300 mL	
		Subdue 2 G	125–250 g/100m^2	Soil surface broadcast application
			250–1000 g/100 m^2	Soil surface incorporation at transplanting
			125 g/m^3	Soil mix at seeding and Transplanting
	Rust	Nova 40W	340 g	
Cineraria	Aphid	Impower 60 WP	Read label carefully	
		Thiodan 50 WP	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
		Endosulfan 400	1.25 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Sulfotep Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
	Fungus gnat	Citation 75WP	75 g/570 L	
		Dimilin 25WP	18–150 g	
		Vectobac 600L	2–8 L	
	Two-Spotted Spider Mite	Kelthane 50 W	525–700 g	
		Avid 1.9% EC	300 mL	
		Insecticidal Soap	20–25 L	
	Whitefly	Impower 60 WP	Read label carefully	
		Thiodan 50 WP	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Dibrom Insecticide	10 mL/100 m^3	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Pounce 384 EC	275 mL	
		Insecticidal Soap	10 L	See Pesticide Injury To Flower Crops on page 38.
	Thrips	Decis 5.0 EC	0.35–0.5 L	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops
		Botran 75% WP	925 g	
		Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
		Rovral 50% WP	1.0 kg	
Cyclamen	Aphid	Impower 60 WP	Read label carefully	
		Nicotine Smoke Fumigator	1/300 m^3	
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Sulfotep Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
	Cyclamen Mite	Kelthane 50 W	525–700 g	
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
		Endosulfan 400	1.25 L	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25 WP	18–150 g	
		Vectobac 600 L	2–8 L	
	Two-Spotted Spider Mite	Avid 1.9% EC	300 mL	
		Insecticidal Soap	20 L	
		Dyno-Mite 75 W	142–284 g	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying new crops.
		Phyton-27	1.25–2.5 L	
		Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
		Rovral 50% WP	1.0 kg	
		Exotherm Termil Smoke Fumigator	1/100 m^2	
Exacum	Two-Spotted Spider Mite	Avid 1.9% EC	300 mL	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying new crops.
		Rovral 50% WP	1.0 kg	
Foliage Plants	**Note: Due to the diversity of foliage plants and the lack of factual information on varietal damage, these recommendations are for trial use only**			
	Aphid	Pirliss 50 WDG	500 g	
		Impower 60 WP	Read label carefully	
		Malathion 50 EC	2.0 L	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 50 WP	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		DDVP Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Sulfotep Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	
		Dibrom Insecticide	10 mL/100 m^3	
	Brown Soft Scale	Malathion 50% EC	2.0 L	See Pesticide Injury To Flower Crops on page 38.
		Sulfotep Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	
		Insecticidal Soap	20 L	
	Cyclamen Mite	Kelthane 50 W	525–700 g	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25 WP	18–150 g	
		Vectobac 600 L	2–8 L	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
	Mealybug	Malathion 50% EC	2.0 L	See Pesticide Injury To Flower Crops on page 38.
		DDVP Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		Trumpet 80 W	0.75–1.0 kg	
		Dibrom Insecticide	10 mL/100 m^3	
	Two-Spotted Spider Mite	Avid 1.9% EC	300 mL	
		Kelthane 50 W	525–700 g	
		Dyno-Mite 75 W	142ñ284 g	
	Whitefly	Impower 60 WP	Read label carefully	
		Ambush 50 EC	200 mL	
		Dyno-Mite 75 W	284–425 g	
		Trumpet 80 W	0.75–1.0 kg	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Pounce 384 EC	275 mL	
		Insecticidal Soap	10 L	
	Root Rot (Cuttings)	Truban 30% WP	190–750 g	
	Phytophthora	Truban 25 EC	300–630 mL	
		Aliette	2.8 kg/ha	Foliar application
	Rhizoctonia	Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
		Daconil 2787	2.5 L	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops.
		Rovral 50% WP	1.0 kg	
	Leaf Spots and Blights	Daconil 2787	2.5 L	
Geranium	Aphid	Pirliss 50 WDG	500 g	
		Impower 60 WP	Read label carefully	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Trumpet 80 W	0.75–1.0 kg	
		Enstar 65 II	250–400 mL	
		Nicotine Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		Sulfotep Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25 WP	18–150 g	
		Vectobac 600L	2–8 L	
	Mealybug	Trumpet 80 W	0.75–1.0 kg	
		Malathion 50% EC	2.0 L	
		Dibrom Insecticide	10 mL/100 m^3	
	Two-Spotted Spider Mite	Kelthane 50 W	525–700 g	
		Avid 1.9% EC	300 mL	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
		Insecticidal Soap	20–25 L	
		Dyno-Mite 75 W	142–284 g	
	Thrips	Decis 5.0 EC	0.35–0.5 L	
	Whitefly	Impower 60 WP	Read label carefully	
		Trumpet 80 W	0.75–1.0 kg	
		Enstar II	250–400 mL	
		Sulfotep Smoke Fumigator	1/300 m3	
		Dibrom Insecticide	10 mL/100 m^3	
		Pounce 384 EC	275 mL	
		Dyno-Mite 75 W	284–425 g	
		Ambush 50 EC	200 mL	
		Thiodan 50 WP	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Insecticidal Soap	10 L	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops.
		Phyton-27	1.25–2.5 L	
		Botran 75% WP	925 g	
		Exotherm Termil Smoke Fumigator	1/100 m^2	
		Daconil 2787	2.5 L	Foliage only
		Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
		Rovral 50% WP	1.0 kg	
	Damping-Off	Truban 25 EC	300–630 mL	
	Stem and Root Rots	Subdue 2 G	125–250 g/100 m^2	Soil surface broadcast application
			125–1000 g/100 m^2	Soil surface incorporation at transplanting
			125 g/m^3	Soil mix at seeding and transplanting
	Rust	Nova 40 W	340 g	
		Daconil 2787	2.5 L	Foliage only
Gerbera	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25 WP	18–150 g	
		Vectobac 600L	2–8 L	
	Leafminer	Avid 1.9 % EC	600 mL	
		Citation 75 WP	75 g/400 L	
	Two-Spotted Spider Mite	Dyno-Mite 75W	142–284 g	
		Avid 1.9% EC	300 mL	
		Kelthane 50 W	525–700 g	
	Thrips	Diazinon 50% WP	1.0–1.5 kg	
		Diazinon 50% EC	1.0 L	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
	Whitefly	Impower 60 WP	Read label carefully	Coconut growing medium may bind Impower, making it unavailable to plants.
		Dyno-Mite 75W	284–425 g	
		DDVP 20 % EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Insecticidal Soap	10 L	
Gloxinia	Aphid	Impower 60 WP	Read label carefully	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 50 WP	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		DDVP Smoke Fumigator	1/300 m^3	
		Dibrom Insecticide	10 mL/100 m^3	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25WP	18–150 g	
		Vectobac 600 L	2–8 L	
	Thrips	Diazinon 50% WP	1.0–1.5 kg	
		Diazinon 50% EC	1.0 L	
	Two-Spotted Spider Mite	Kelthane 50 W	525–700 g	
		Avid 1.9% EC	300 mL	
		Insecticidal Soap	20 L	
	Root and Stem Rot	Subdue 2 G	125–250 g/100 m^2	Soil surface broadcast application
			250–1000 g/100 m^2	Soil surface incorporation at transplanting
			125 g/m^3	Soil mix at seeding and transplanting
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops
		Rovral 50% WP	1.0 kg	
		Exotherm Termil Smoke Fumigator	1/100 m^2	
		Daconil 2787	2.5 L	
	Powdery mildew	Nova 40 W	340 g	
Gypsophila	Leafminer	Avid 1.9% EC	600 mL	
		Citation 75 WP	75 g/400L	
	Two-Spotted Spider Mite	Avid 1.9% EC	300 mL	
		Kelthane 50 W	525–700 g	
	Thrips	Diazinon 50% WP	1.0–1.5 kg	
		Diazinon 50% EC	1.0 L	
Hydrangea	Aphid	Impower 60 WP	Read label carefully	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
		Trumpet 80 W	0.75–1.0 kg	
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400		
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6L	See Pesticide Injury To Flower Crops on page 40.
		Dibrom Insecticide	10mL/100 m^3	
		Enstar II	250–400 mL	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25 WP	18–150 g	
		Vectobac 600 L	2–8 L	
	Two-Spotted Spider Mite	Kelthane 50 W	525–700 g	
		Avid 1.9% EC	300 mL	
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		Insecticidal Soap	20 L	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops.
		Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
		Rovral 50% WP	1.0 kg	
		Exotherm Termil Smoke Fumigator	1/100 m^2	
		Daconil 2787	2.5 L	On foliage only
	Leaf Spots	Daconil 2787	2.5 L	
	Rust	Daconil 2787	2.5 L	
Lily (Easter)	Aphid	Impower 60 WP	Read label carefully	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	20 L	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25 WP	18-150 g	
		Vectobac 600 L	2–8 L	
	Two-Spotted Spider Mite	Dyno-Mite 75W	284–425 g	
		Avid 1.9% EC	300 mL	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
		Insecticidal Soap	20 L	
	Thrips	Decis 5.0 EC	0.35–0.5 L	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops.
		Exotherm Termil Smoke Fumigator	1/100 m^2	
		Rovral 50% WP	1.0 kg	
		Daconil 2787	2.5 L	
	Root Rot	Truban 30% WP	175–625 g	
Poinsettia	Brown Soft Scale	Sulfotep Smoke Fumigator	1/300 m^3	
		Malathion 50% WP	2.0 kg	
		Insecticidal Soap	20 L	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Vectobac 600 L	2–8 L	
	Mealybug	Malathion 50% EC	2.0 L	
		DDVP Smoke Fumigator	1/300 m^3	
		Parathion Smoke Fumigator	1/300 m^3	
		Dibrom Insecticide	10 mL/100 m^3	
	Two-Spotted Spider Mite	Kelthane 50 W	525–700 g	
		Avid 1.9% EC	300 mL	
		Dyno-Mite 75 W	142–284 g	Avoid pesticide application after bract colour, as damage may occur.
	Whitefly	Impower 60 WP	Read label carefully	
		Sulfotep Smoke Fumigator	1/300 m^3	
		DDVP Smoke Fumigator	1/300 m^3	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Dyno-Mite 75 W	284–425 g	Avoid pesticide application after bract colour, as damage may occur.
		Thiodan 50 WP	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Endosulfan 50 W	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Ambush 50 EC	200 mL	
		Enstar II	250–400 mL	Do not apply after September 15
		Pounce 384	275 mL	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops.
		Daconil 2787	2.5 L	
		Exotherm Termil Smoke Fumigator	1/100m^2	
		Rovral 50% WP	1.0 kg	
		Botran 75% WP	925 g	
		Phyton-27	1.25–2.5 L	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
	Damping-Off Stem Rots	Subdue 2 G	125–250 g/100m^2	Soil surface broadcast application
			250–1000 g/100 m^2	Soil surface incorporation at transplanting
			125 g/m^3	Soil mix at seeding and transplanting
	Powdery mildew	Nova 40 W	280 g	
		Phyton-27	1.25 L	
	Rhizoctonia Stem Rot	Quintozene 75% WP	1.0–1.25 kg/100 m^2	
	Root Rot (*Pythium/ Phytophthora*)	Subdue 2 G	125–250 g/100m^2	Soil surface broadcast application
			250–1000 g/100 m^2	Soil surface incorporation at transplanting
			125 g/m^3	Soil mix at seeding and transplantingPre-plant dip
	(*Rhizoctonia*)	Quintozene 75% WP	0.98–2.73 kg/100 m^2	
	Erwinia	Phyton-27	1.25–1.5 L	
Rose	Aphid	Pirliss 50 WDG	500 g	
		Impower 60 WP	Read label carefully	
		DDVP Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Enstar II	250–400 mL	May damage some varieties
		Trumpet 80 W	0.75–1.0 kg	
		Nicotine Smoke Fumigator	1/300 m^3	
		Orthene 75% SP	850 g	
		Insecticidal Soap	20 L	
		Dibrom Insecticide	10 mL/100m^3	
	Brown Soft Scale	Malathion 50% EC	2.0 L	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	
		Insecticidal Soap	10 L	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25 WP	18–150 g	
		Vectobac 600 L	2–8 L	
	Leafroller	Dipel	1.0–1.25 kg	
		Orthene 75% SP	850 g	
		Dibrom Insecticide	10 mL/100m^3	
	Midge	Orthene 75% SP	850 g	
		Parathion Smoke Fumigator	1/300 m^3	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Diazinon 50% WP	1.0–1.5 kg	Soil drench
		Diazinon 50% EC	1.0 L	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
	Thrips	Trumpet 80 W	0.75–1.0 kg 1.25 kg/ha	Drench
		Orthene 75 SP	850 g	
		Diazinon 50% WP	1.0–1.5 kg	
		Diazinon 50% EC	1.0 L	Soil drench
	Two-Spotted Spider Mite	Kelthane 50 W	525–700 g	
		Insecticidal Soap	20 L	
		Avid 1.9% EC	300 mL	
		Dibrom Insecticide	10 mL/100m^3	
		Dyno-Mite 75W	142–284 g	
	Whitefly	Impower 60 WP	Read label carefully	Coconut growing medium may bind Impower, making it unavailable to plants.
		Ambush 50 EC	200 mL	
		Dyno-Mite 75 W	284–425 g	
		Insecticidal Soap	10 L	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	
		Enstar II	250–400 mL	May damage some varieties
		Thiodan 50 WP	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Thiodan 4 EC	1.25 L	See Pesticide Injury To Flower Crops on page 38.
		Endosulfan 50 W	1.0 kg	See Pesticide Injury To Flower Crops on page 38.
		Endosulfan 400	1.25 L	See Pesticide Injury To Flower Crops on page 38.
		Orthene 75% SP	850 g	
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Pounce 384 EC	275 mL	
		Dibrom Insecticide	10 mL/100 m^3	
	Black Spot	Daconil 2787	2.5 L	
		Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
	Powdery Mildew	Nova 40 W	340 g	
		Meltatox 40% EC	2.5 L	
		Phyton-27	1.25–2.5 L	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops.
		Rovral 50 WP	1.0 kg	
		Daconil 2787	2.5 L	
		Phyton-27	1 L	Dip flower/bud for 4 seconds shortly after harvesting
Snapdragon	Aphid	Pirliss 50 WDG	500 g	
		Impower 60 WP	Read label carefully	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
		Nicotine Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		DDVP Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Sulfotep Smoke Fumigator	1/300 m^3	
		Trumpet 80 W	0.75–1.0 kg	
		Insecticidal Soap	20 L	
	Cyclamen Mite	Kelthane 50 W	525–700 g	
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
	Fungus gnat	Citation 75 WP	75 g/570 L	
		Dimilin 25 WP	18–150 g	
		Vectobac 600 L	2–8 L	
	Thrips	Trumpet 80 W	0.75–1.0 kg	
		Diazinon 50% WP	1.0–1.5 kg	
		Diazinon 50% EC	1.0 L	
	Two-Spotted Spider Mite	Avid 1.9% EC	300 mL	
		Insecticidal Soap	20 L	
		Kelthane50 W	525–700 g	
		Dyno-Mite 75 W	142–284 g	
		Dibrom Insecticide	10 mL/100 m^3	
	Whitefly	Impower 60 WP	Read label carefully	
		Thiodan 50 WP	1.0 kg	
		Thiodan 4 EC	1.25 L	
		Endosulfan 50 W	1.0 kg	
		Endosulfan 400	1.25 L	
		DDVP Smoke Fumigator	1/300 m^3	See Pesticide Injury To Flower Crops on page 38.
		DDVP 20% EC	6 L	See Pesticide Injury To Flower Crops on page 38.
		Trumpet 80 W	0.75–1.0 kg	
		Dyno-Mite 75 W	284–425 g	
		Dibrom Insecticide	10 mL/100 m^3	
		Sulfotep Smoke Fumigator	1/300 m^3	
		Insecticidal Soap	10 L	
	Botrytis	Decree 50 WDG	1.12 kg/ha	Test on a few plants before applying to new crops.
		Exotherm Termil Smoke Fumigator	1/100 m^2	
		Captan 50% WP	2.0 kg	
		Captan 80% WP	1.5 kg	
		Maestro 75 DF	1.5 kg	
		Daconil 2787	2.5 L	
		Rovral 50% WP	1.0 kg	

TABLE 10–1. Pesticide Recommendations for Greenhouse Flower Crops

Plant Name	Problem	Recommendation by Trade Name	Rate/1000 L (exceptions noted)	Remarks
	Stem Rot	Truban 25 EC	240–300 mL	
		Truban 30% WP	175–625 g	

Appendix A: Conversions

The Metric System

Linear Measures (length)

10 millimetres (mm) = 1 centimetre (cm)
100 centimetres (cm) = 1 metre (m)
1000 metres = 1 kilometre (km)

Square Measures (area)

100 m X 100 m = 10,000 m^2 = 1 hectare (ha)
100 ha = 1 square kilometre (km^2)

Cubic Measures (volume)

Dry Measure

1000 cubic millimetres (mm^3)= 1 cubic centimetre (cm^3)
1,000,000 cm^3 = 1 cubic metre (m^3)

Liquid Measures

1000 millilitres (mL) = 1 litre (L)
100 L = 1 hectolitre (hL)

Weight-Volume Equivalents (for water)

(1.00 kg) 1000 grams = 1 litre (1.00 L)
(0.50 kg) 500 g = 500 mL (0.50 L)
(0.10 kg) 100 g = 100 mL (0.10 L)
(0.01 kg) 10 g = 10 mL (0.01 L)
(0.001 kg) 1 g = 1 mL (0.001 L)

Weight Measures

1000 milligrams (mg) = 1 gram (g)
1000 g = 1 kilogram (kg)
1000 kg = 1 tonne (t)
1 mg/kg = 1 part per million (ppm)

Dry/Liquid Equivalents

1 cm^3 = 1 mL
1 m^3 = 1000 L

Application Rate Conversions

Metric to Imperial (Approximate)

litres per hectare x 0.09 = gallons per acre
litres per hectare x 0.36 = quarts per acre
litres per hectare x 0.71 = pints per acre
millilitres per hectare x 0.015 = fluid ounces per acre
grams per hectare x 0.015 = ounces per acre
kilograms per hectare x 0.89 = pounds per acre
tonnes per hectare x 0.45 = tons per acre

Imperial to Metric (Approximate)

gallons per acre x 11.23 = litres per hectare (L/ha)
quarts per acre x 2.8= litres per hectare (L/ha)
pints per acre x 1.4 = litres per hectare (L/ha)
fluid ounces per acre x 70 = millitres per hectare (mL/ha)
tons per acre x 2.24 = tonnes per hectare (t/ha)
pounds per acre x 1.12 = kilograms per hectare (kg/ha)
ounces per acre x 70 = grams per hectare (g/ha)

Calculating Parts Per Million (ppm)

1 ppm = 1 g active ingredient per 1000 L water

Liquid Equivalents

Litres/ Hectare	*Approximate Gallons/Acre*
50	= 5
100	= 10
150	= 15
200	= 20
250	= 25
300	= 30

Dry Weight Equivalents

Grams or Kilograms per Hectare	*Ounces or Pounds per Acre*
100 grams	= 1 1/2 ounces
200 grams	= 3 ounces
300 grams	= 4 1/4 ounces
500 grams	= 7 ounces
700 grams	= 10 ounces
1.10 kilograms	= 1 pound
1.50 kilograms	= 1 1/4 pounds
2.00 kilograms	= 1 3/4 pounds
2.50 kilograms	= 2 1/4 pounds
3.25 kilograms	= 3 pounds

4.00 kilograms = 3 1/2 pounds
5.00 kilograms = 4 1/2 pounds
6.00 kilograms = 5 1/4 pounds
7.50 kilograms = 6 3/4 pounds
9.00 kilograms = 8 pounds
11.00 kilograms = 10 pounds
13.00 kilograms = 11 1/2 pounds
kilograms = 13 1/2 pounds

Metric Conversions

5 mL = 1 tsp
15 mL = 1 tbsp
28.5 mL = 1 fl. oz.

Handy Metric Conversion Factor

Litres per Hectare x 0.4 = Litres per Acre
Kilograms per Hectare x 0.4 = Kilograms per Acre

Conversion Tables—Metric to Imperial

Length

1 millimetre (mm) = 0.04 inch
1 centimetre (cm) = 0.40 inch
1 metre (m) = 39.40 inches
1 metre (m) = 3.28 feet
1 metre (m) = 1.09 yards
1 kilometre (km) = 0.62 mile

Volume (liquid)

1 millilitre (mL) = 0.035 fluid ounce
1 litre (L) = 1.76 pints
1 litre (L) = 0.88 quart
1 litre (L) = 0.22 gallon (Imp.)
1 litre (L) = 0.26 gallon (U.S.)

Weight

1 gram (g) = 0.035 ounce
1 kilogram (kg) = 2.21 pounds
1 tonne (t) = 1.10 short tons
1 tonne (t) = 2205 pounds

Pressure

1 kilopascal (kPa) = 0.15 pounds/in

Area

1 square centimetre (cm$^{2)}$ = 0.16 square inch
1 square metre (m^2) = 10.77 square feet
1 square metre (m^2) = 1.20 square yards
1 square kilometre (km^2) = 0.39 square mile
1 hectare (ha) = 107,636 square feet
1 hectare (ha) = 2.5 acres

Volume (dry)

1 cubic centimetre (cm^3) = 0.061 cubic inch
1 cubic metre (m^3) = 1.31 cubic yards
1 cubic metre (m^3) = 35.31 cubic feet
1000 cubic metres (m^3) = 0.81 acre-foot
1 hectolitre (hL) = 2.8 bushels

Speed

1 metre per second = 3.28 feet per second
1 metre per second = 2.24 miles per hour
1 kilometre per hour = 0.62 mile per hour

Temperature

°F = (°C X 9/5) + 32

Conversion Tables—Imperial to Metric

Length

inch	= 2.54 cm
foot	= 0.30 m
yard	= 0.91 m
mile	= 1.61 km

Area

square foot	= 0.09 m^2
square yard	= 0.84 m^2
acre	= 0.40 ha

Weight

ounce	= 28.35 g
pound	= 453.6 g
ton	= 0.91 tonne

Volume (dry)

cubic yard	=0.76 m^3
bushel	= 36.37 L

Volume (liquid)

fluid ounce (Imp.)	= 28.41 mL
pint (Imp.)	= 0.57 L
gallon (Imp.)	= 4.55 L
gallon (U.S.)	= 3.79 L

Pressure

pound per square inch	= 6.90 kPa

Temperature

°C = (°F - 32) x 5/9

Abbreviations

% = per cent (by weight)
ai = active ingredient
AP = agricultural powder
cm = centimetre
cm^2 = square centimetre
DG = dispersible granular
DP = dispersible powder
E = emulsifiable
e.g., = for example
EC = emulsifiable concentrate
F = flowable
g = gram
Gr = granules, granular
ha = hectare
kg = kilogram
km = kilometre
km/h = kilometres per hour
kPa = kilopascal
L = litre
m = metre
m/s = metres per second
m^2 = square metre
mL = millilitre
mm = millimetre
SC = sprayable concentrate
SP = soluble powder
t = tonne
W = wettable (powder)
WDG = water dispersible granular
WP = wettable powder

Appendix B: Diagnostic Service

Samples for disease diagnosis, insect or weed identification, nematode counts, and Verticillium testing can be sent to:

Pest Diagnostic Clinic
Laboratory Services Division
University of Guelph
95 Stone Rd. W.,
Guelph, Ont., N1H 8J7
Telephone (519) 767-6256 Fax (519) 767-6240
E-mail: pdc@lsd.uoguelph.ca
www.uoguelph.ca/pdc/

Sample submission forms are available at OMAFRA offices or directly from the clinic. Payment must accompany samples at the time of submission.

TABLE B–1. Fee Schedule for Pest Diagnostic Clinic (University of Guelph)

Procedures	**Price/Sample**
Plant Diseases	
Diagnosis not requiring plating	$25.00
Diagnosis requiring plating	$40.00
Turf Diagnosis	$50.00
Bacterial Identification using Biolog®	$95.00
Detection of virus using Transmission Electron Microscopy	$85.00
Detection of virus using ELISA (turnaround time: 5 business days)	$60
Detection of virus using ELISA (RUSH: 24-hour turnaround)*	$120/ 1 to 6 samples
*Available for samples received Monday through Thursday. *Each additional sample is $20.00.* ELISA tests not available for all viruses, contact clinic staff for details	
Weed Identification	
Weed Identification	$40.00
Insects	
Basic Identification	$25.00
Identification requiring dissection and/or extensive keys	$40.00

Nematode and Verticillium Counts	**Price/Sample[1] [2]**
Nematodes extracted from soil (Bearman Pan Method)	$25.00
Nematodes extracted from roots	$60.00
Verticillium count	$60.00
SCN Cyst count + Egg Count	$35.00

[1] A minimum fee of $25.00 should accompany all submissions.

[2] **Payment:** Please make cheque payable to the University of Guelph. Additional charges will be invoiced with the final report. VISA and Mastercard are also accepted. Please do not mail cash.

How to Sample for Nematodes

Soil

When to Sample

Soil and root samples can be taken at any time of the year when the soil is not frozen. In Ontario nematode soil population levels are generally at their highest in May–June and again in September–October.

How to Sample Soil

Samples should be taken with a soil-sampling tube, trowel, or narrow-bladed shovel. Soil should be sampled to a depth of 20–25 cm (8–10 in). If the soil is bare, the top 2 cm (1 in.) should be removed prior to sampling. A sample should consist of 10 or more subsamples combined. Mix well. Then take a sample of 1/2 L to 1 L (1 pint to 1 quart) from this. No one sample should represent more than 2.5 ha (6.25 ac.) Subsamples should be mixed in a clean pail or plastic bag.

Sampling Pattern

If living crop plants are present in the sample area, samples should be taken within the row and from the area of the feeder root zone (with trees, this is the drip line).

Number of Subsamples

Based on the total area sampled:

500 m^2 (5,400 ft^2)	10 subsamples
500 m^2-0.5 ha (5,400 ft^2-1.25 ac.)	25 subsamples
0.5 ha–2.5 ha (1.25–6.25 ac.)	50 subsamples

Roots

For small plants, sample entire root system plus adhering soil. For large plants, 10–20 g (1/2 oz. to 1 oz.) fresh weight should be dug from the feeder root zone and submitted.

Problem Areas

Soil and root samples should be taken from the margins of the problem area where the plants are still living. If possible, samples should also be taken from healthy areas in the same field. If possible, both soil and root samples should be taken from problem and healthy areas in the same field.

Sample Handling

Soil Samples

Place in plastic bags as soon as possible after collecting.

Root Samples

Place in plastic bags and cover with moist soil from the sample area.

Storage

Samples should be stored between 5°C and 10°C (40°F–50°F) and should not be exposed to direct sunlight or extreme heat or cold (freezing). **Only living nematodes can be counted. Accurate counts are dependent on proper handling of samples**

Submitting Plants for Disease Diagnosis or Identification

Carefully complete all categories on the form. In the space provided, draw the most obvious symptom and the pattern of the disease in the field. It is important to include the cropping history of the area for the past three years and this year's pesticide use records.

Choose a complete representative sample showing early symptoms. Submit as much of the plant as is practical, including the root system, or several plants showing a range of symptoms. For turfgrass, submit a 10–15 cm square piece of turf, including thatch and at least 5 cm of soil. The sample should be taken from the outside edge of a ring or patch and include healthy and unhealthy turf and the interface between. If symptoms are general, collect the sample from an area where they are of intermediate severity. **Completely dead material is usually inadequate for diagnosis.** Plant specimens submitted for identification should at least include a 20–25 cm sample of the top portion of the stem with lateral buds, leaves, flowers, or fruits in identifiable condition. Wrap plants in newspaper and put in a plastic bag. Tie the root system off in a separate plastic bag to avoid drying out and soil contamination of the leaves. Do NOT add moisture, as this encourages decay in transit. Cushion specimens and pack in a sturdy box to avoid damage during shipping. Avoid leaving specimens to bake or freeze in a vehicle or in a location where they could deteriorate.

Delivery to the Pest Diagnostic Clinic should be made as soon as possible by first class mail or by courier at the beginning of the week.

Submitting Insect Specimens for Identification

Collecting Samples

Dead, hard-bodied insects and spiders should be placed in vials or boxes and cushioned with tissues or cotton. Soft-bodied insects and caterpillars should be placed in vials containing alcohol. Do not use water as this will result in rot. Do not tape insects to paper or send them loose in an envelope.

Live insects should be placed in a container with enough plant "food" to support them during transit. Be sure to write "live" on the outside of the container.

Appendix C: Ontario Ministry of the Environment Pesticide Control Offices

Region/County	Pesticides Officer/Address	Telephone
Central Region Toronto, Halton, Peel, York, Durham	**Charles Zubovits** 5775 Yonge St, 8th Floor Toronto, Ontario M2M 4J1	(416) 326-3671 Toll Free 1-800-810-8048 Fax (416) 325-6347
West-Central Region Haldimand-Norfolk, Niagara, Hamilton-Wentworth, Dufferin, Wellington, Waterloo, Brant	**Paul McCubbin** Linda Gabriele Ontario Government Building 119 King St. West, 12th Floor Hamilton, Ontario L8P 3Y9	(905) 521-7667 (905) 521-7658 Fax (905) 521-7820
Eastern Region Frontenac, Hastings, Lennox & Addington, Prince Edward, Leeds & Grenville, Prescott & Russell, Stormont/Dundas & Glengarry Peterborough, Victoria, Northumberland, Renfrew, Ottawa-Carleton, Lanark, District of Nipissing (Townships of Airy, Murchison, Dickens, Lyell and Sabine)	**Andrew Morley** 133 Dalton Avenue P.O. Box 820 Kingston, Ontario K7L 4X6	(613) 549-4000 ext 2684 Fax (613) 548-6908 Toll Free 1-800-267-0974
Southwestern Region Elgin, Middlesex, Oxford,Essex, Kent, Lambton, Bruce, Grey, Huron, Perth, Simcoe	**Doug Morrow** Wray Lampman 659 Exeter Road, 2nd Floor London, Ontario N6E 1L3	(519) 873-5047 (519) 873-5048 Fax (519) 873-5000
Northern Region Manitoulin, Nipissing, Parry Sound, Sudbury, Algoma East, Cochrane East, Haliburton, Muskoka, Kenora, Rainy River, Thunder Bay, Algoma West, Cochrane West	**Ray Potvin** John Negusanti 199 Larch Street, Ste 1101 Sudbury, Ontario P3E 5P9	(705) 564-3247 (705) 564-3249 Fax (705) 564-4180
Standards Development Branch	Pesticides Section (Mailing Address) 135 St. Clair Avenue West Toronto, Ontario M4V 1P5	(416) 327-5519 Fax (416) 327-2936
Approvals Branch	Pesticides Licensing 250 Davisville Avenue, 3rd Floor Toronto, Ontario M4S 1H2	(416) 440-3584 Toll Free 1-800-461-6290 Fax (416) 440-6973

Appendix D: Ontario Ministry of Agriculture, Food and Rural Affairs Floriculture Advisory Staff

Wayne Brown

Greenhouse Floriculture Specialist

Vineland, Department of Plant Agriculture, University of Guelph

Phone: (905) 562-4141 ext 179

Fax: (905) 562-3413

E-mail: wayne.brown@omafra.gov.on.ca

Graeme Murphy

Greenhouse Floriculture IPM Specialist

Vineland, Department of Plant Agriculture, University of Guelph

Phone: (905) 562-4141 ext 106

Fax: (905) 562-3413

E-mail: graeme.murphy@omafra.gov.on.ca

A complete list of Ontario Ministry of Agriculture, Food and Rural Affairs Advisory Staff is available on our Web site

www.gov.on.ca/OMAFRA/crops

Appendix E: Other Contacts

University of Guelph

Main Campus, Guelph, N1G 2W1 (519) 824-4120

Alfred College, Alfred, K0B 1A0, (613) 679-2218

Kemptville College, Kemptville, K0G 1J0, (613) 258-8336

Ridgetown College, Ridgetown, N0P 2C0, (519) 674-1500

Department of Plant Agriculture, Kettleby 1125 Woodchopper's Lane, R.R. # 1, Kettleby, L0G 1J0, (905) 775-3783

Department of Plant Agriculture , Simcoe, Box 587 Blue Line Rd., Simcoe, N3Y 4N5, (519) 426-7127

Department of Plant Agriculture, Vineland, Box 7000, 4890 Victoria Ave. N., Vineland Station, L0R 2E0, (905) 562-4141

Lab Services Division

Pesticide and Trace Contaminants, P.O.Box 3650, 95 Stone Road, West, Guelph, N1H 8J7, (519) 767-6200

Pest Diagnostic Clinic (519) 767-6256

Agriculture & Agri-Food Canada

Research Centres

Eastern Cereals and Oilseeds Research Centre, 960 Carling Avenue, Ottawa, K1A 0C6, (613) 759-1952

Greenhouse and Processing Crops Centre, Harrow N0R 1G0, (519) 738-2251

Southern Crop Protection and Food Research Centre 1391 Sandford St., London N5V 4T3 (519) 457-1470

Vineland Research Farm, 4902 Victoria Ave. N., Vineland L0R 2E0 (905) 562-4113

Delhi Research Farm, Box 186 Schafer Rd., Delhi N4B 2W9 (519) 582-1950

Canadian Food Inspection Agency

Regional Offices (Plant Protection)

Belleville—345 College Street East, Belleville, K8N 5S7, (613) 969-3333

Hamilton—709 Main St. W. Suite 101, Hamilton, L8S 1A2, (905) 572-4152

London—457 Richmond St., Suite 404, London, N6A 3E3, (519) 645-4021

Niagara Falls—(Mailing address) R.R #1 P.O. Box #7, Niagara on the Lake, L0S 1J0

Niagara Falls—(Street address) 14154 Niagara River Parkway, Unit # 5., Niagara on the Lake, (905) 262-5331

Brantford—Federal Building, Dalhousie & Queen St, P.O. Box 637, Brantford, N3T 5P9 (519) 751-8157

Ottawa District—3 Observatory Crescent, Bldg., #3 Central, Experimental Farm, Ottawa, K1A 0C9, (613) 759-1571

Toronto Office—401 Champagne Drive, Unit 1, Downsview, M3J 2C6, (416) 954-1714

Windsor—441 University Ave. W., Suite 208, Windsor, N9A 5P9, (519) 252-7095

Emergency and First-Aid Procedures for Pesticide Poisoning

- Become familiar with the chemicals you are using. Keep a list of common names in case of accidents or emergencies. This information can be found on the product labels and cross-referenced in this publication.
- If a pesticide has come in contact with the skin or has been spilled on clothing, remove the clothing and wash the skin thoroughly with soap and warm water.
- If pesticide has come in contact with the eyes, rinse them with plenty of clean water for 15 minutes. Repeat this procedure.
- If a person suspects poisoning from exposure to a pesticide by swallowing, inhalation, or contact with skin or eyes, read the label on the pesticide container and carry out the first-aid treatment suggested.
- **Immediately after first-aid treatment has been given, wrap the patient in a coat or blanket and rush him/her to the nearest hospital. Take the list of chemical common names with you and identify the ones being used.**
- **If a person is unconscious or lapses into unconsciousness, call an ambulance immediately.**
- **Emergency advice on pesticide poisoning is available from the Regional Poison Information Centres at:**

  Toronto 1-800-268-9017 Ottawa (bilingual) 1-800-267-1373

- **Those needing hearing assistance should call: 1-416-597-0215 (TTY)**

  Emergency telephone numbers are listed at the front of each Bell telephone directory.

  Fill in the following:

  My Local Poison Information Centre Telephone Number is:

  ______-______________________________________

For information, or to obtain copies of this or any other ministry publication, please: call 1-888-4-OMAFRA (1-888-466-2372) from within Ontario, (519) 826-3700 from outside the province or OMAFRA's TTY line at (519) 826-7402 for the hearing impaired, email your request to *products@omafra.gov.on.ca*, or visit OMAFRA's web site at *www.gov.on.ca/omafra*.

A complete listing of all OMAFRA products and services, and order forms, are available on the web site. Orders can be faxed to (519) 826-3633 or mailed to Government Information Centre, OMAFRA, 1 Stone Road West, Guelph, ON N1G 4Y2

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